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NAWC Retrievable Manuscript
RM-24

Collected Speeches of

Dr. William B. McLean

Technical Director,
Naval Ordnance Test Station, 1954-1967

Technical Information Department
September 1993

NAVAL AIR WARFARE CENTER WEAPONS DIVISION
CHINA LAKE, CALIFORNIA 93555-6001

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This Retrievable Manuscript, RM-24, is being distributed to China Lake's management team at the suggestion of members of the NOTS/NWC 50th Anniversary Committee; the intent is to provide a wider opportunity to benefit from a collection of Dr. William B. McLean's speeches that heretofore has been available only in the reference collection of the Technical Library. Other speeches found in TID's Collection of Archival and Reference Documents (CARD) have been added in order to make this collection as comprehensive as possible.

In the early 1970s, when most of these speeches were added to the Technical Library collection, some of the speeches were retyped or partially retyped from Dr. McLean's original drafts. No additional changes have been made, however, for this RM (except that page numbers have been added and the speeches have been categorized and summarized on divider sheets to assist the user in locating topics of interest).

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L. L. DOIG III
Command Historian
C6406
21 September 1993

Dr. William B. McLean, NOTS Technical Director, 1954-67. He is shown wearing the gold medal he received from President Eisenhower at a special ceremony at the White House on January 27, 1958.

Introduction

> I consider my position as Technical Director of the Naval Ordnance Test Station the most challenging and interesting civilian scientific position in the Navy. Our ability to combine the functions of research, development, and test represents an opportunity for effective missile and ordnance development which seems to me to be unequalled anywhere in the country.
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> — Dr. William B. McLean letter Code 01/WBM:nft of 29 May 1957 to Rear Admiral James S. Russell, USN, Chief, Bureau of Aeronautics

This manuscript publication is a collection of speeches and papers written by Dr. William B. McLean during the years he was Technical Director of the Naval Ordnance Test Station (NOTS), predecessor organization to the Naval Air Warfare Center Weapons Division (NAWC), China Lake. These representative expressions of McLean's thoughts are being made available, not just because of their significance to China Lake's history, but also because of their pertinence to the Center's—and the Navy's—administrative and technical problems of today.

A brief recitation of the facts of McLean's life can only hint at his accomplishments. Born in Portland, Oregon, in May 1914, he attended Eagle Rock High School in Los Angeles, and then the California Institute of Technology, Pasadena, from which he received his B.S., M.S., and Ph.D. degrees in physics. From 1935 to 1939 he was a physics instructor at CalTech. In 1939 he became a research associate in nuclear physics at the University of Iowa, Iowa City, leaving there in 1941 to join the technical staff of the National Bureau of Standards, Washington, D.C. There he supervised the work of the development section on electronic bomb, rocket, and mortar fuzes, and on mechanisms for release of bombs and rockets from aircraft. He came to NOTS in 1945 as a physicist and head of the fire-control section in the Aviation Ordnance Division of the Test Department. In 1950 he was appointed head of the new Aviation Ordnance Department, a post he held until he became NOTS Technical Director in April 1954.

When the Navy Laboratories were reorganized into Centers of Excellence in 1967, McLean left NOTS to become the Technical Director of the new Naval Undersea Center (NUC), which was formed from the NOTS Pasadena Annex and the undersea technology functions of the former Naval Electronics Laboratory.[1] He continued as NUC Technical Director until his retirement in June 1974, and he died in August 1976 in San Diego. His numerous patents cover an amazing spectrum of invention from gyros to satellites to diving apparatus,

[1]NUC is now the Naval Ocean Systems Center, San Diego.

and his many honors include a $25,000 invention award in 1956 (at that time the highest such award ever given), a Presidential Citation in 1958 for his leadership in the development of the Sidewinder guided missile, and one of NOTS' first two L. T. E. Thompson Awards.[2] NAWC's William B. McLean Award is a fitting memorial, since it recognizes outstanding creativity in furthering the Center's mission, as evidenced by significant inventions.

Although he had a key role in the development of numerous NOTS products, McLean is perhaps best known as the inventor of the Sidewinder heat-seeking air-to-air missile, a weapon that is still in worldwide use more than three decades after its 1956 release to the Fleet. The Sidewinder development story has reached the proportions of legend here at NAWC, where it symbolizes the fierce midnight-oil-burning dedication to the task that we China Lakers have come to think of as the "China Lake way." The project began as a feasibility study in 1949, with much of the work done after normal working hours by McLean and a small, intensely dedicated team. After Sidewinder's dazzling success in its first use in combat,[3] McLean was frequently asked to speak on "lessons learned" from the Sidewinder development program. In several of these speeches, he explained his concept of the 10-percent program and the 100-percent program, a concept colloquially referred to at NOTS as "the carrot and the needle." McLean suggested that a productive development program should have "both a large program, which will provide a safe, scheduled, and well-funded route toward the objectives, and a more risky venture funded at 10 percent of the cost, where we can try out the talents of our creative designers without forcing them to risk the political safety of the nation." [4] With typical enthusiasm for the technical challenge, he observed that in such an eventuality he would always choose the 10-percent effort.

Other ideas expressed herein address the proper role of the in-house laboratory and the defense contractor in the weapons acquisition process, the dynamics of the military-civilian team, and management of the creative scientist or engineer. McLean's nine points for changing a creative organization into one doing only routine work should be "must reading" for any manager wishing to avoid work-force mediocrity. [5] Also of interest are his suggestions for weapons developments of the future, particularly since that future is now upon us.

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[2]The other was given to Dr. Thompson himself.

[3]On September 24, 1958, Chinese Nationalists fired six Sidewinders to knock down four Chinese Communist MIG-17s, evidently so impressing the Communists that they thereafter ceased aerial engagements with the Nationalists.

[4]See "The Sidewinder Missile Program," included in this collection, pp. 15-24.

[5]See "Management and the Creative Scientist," pp. 62-67, this collection.

A sense of McLean's remarkable ability to make things happen infuses this collection. If Bill McLean wanted something done, he would generally find a way to do it, and he was successful at sweeping others along in the wake of his enthusiasm. Dr. Howard Wilcox, who served as McLean's principal assistant in the Sidewinder development, remembers him as "A great picker-upper of other people's ideas, as well as having his own ideas. He was an extremely creative engineer, but he was not proud. He would quickly take hold of any idea, whatever the source, provided it was a good idea. And he dropped his own ideas with great rapidity once he was shown they were wrong. But he would stick tenaciously to his ideas as long as he had not been shown they were wrong."[6] LaV McLean (a NOTS mover and shaker in her own right) remembers her husband as being "... always, always optimistic about things. He knew it would work. He knew it would work. It was just a matter of putting the right thing in the right place and modifying it. ... If things failed, it didn't bother him. I mean, he'd just say, 'Well, we'll just try something different.' ... Fact is, Bill seemed to thrive on problems."[7]

It's a fitting time, as the Center nears its 50th Anniversary on 8 November 1993, to remember the major role Bill McLean had in creating both the products and the attitudes that have been responsible for our exceptional productivity during our half century of RDT&E excellence. The lessons available in the enclosed speeches and papers can help prepare us to face the challenging decades ahead.

STERLING HAALAND
Deputy Commander for R&D

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[6]Dr. Howard Wilcox interview, Navy Laboratories Oral History Collection, NL-T25, September 1980, p. 5.

[7]Mrs. LaVerne McLean interview, NWC Oral History S-113, 18 March 1980, pp. 42-43.

Contents

Managing Successful R&D Programs

This section contains the following speeches in chronological order:

"Is Research Different," invited talk to the Bendix Management Club, Los Angeles, California, 26 April 1952

Pointing out the dual pressures on an organization caused by management's needs for orderly goals and the creative scientist's need for autonomy, McLean discusses his reasons for favoring "the type of management which maximizes enjoyment, participation, and the contributions of individual creativity, rather than the type of management whose goals and objectives are set from the top ... without consideration of possible creative inputs."

"Integrated Facilities for Weapons Development," presented at the Joint IRE-RTCA Meeting, Spring 1957

Focusing on the characteristics of NOTS that made the development of Sidewinder possible, McLean describes the "opportunity for doing effective military development" that drew him to the desert in the first place, as well as the benefits of China Lake's close interaction among research, development, engineering, and test personnel.

"Research and Development of Military Equipment," invited lecture sponsored by the Engineering Lecture Committee, Department of Engineering, University of California, Berkeley, California, 17 April 1959

McLean points out that designing a successful missile is similar to completing a mural in that the finished creation "reflects primarily the skill, ability, and experience of the master artist, but ... also uses the individual skills of his assistants to a maximum." He stresses the importance to such a master designer of a broad educational background in science and engineering.

Summary of panel discussion on "Evaluation and Management of Scientific Proposals," Digest of Proceedings of the Institute for Career Science Executives, National Institutes of Health, Bethesda, Maryland, 12-20 October 1960

The panel (which included representatives from NASA, HEW, and the Bureau of the Budget, as well as McLean) concluded that good basic research could be generated by picking good people, then funding them and giving them free rein to pursue programs that management has determined to be important.

"The Sidewinder Missile Program," presentation at the National Advanced-Technology Management Conference, Seattle, Washington, 5 September 1962

This is an excellent summary from McLean's perspective of why the Sidewinder development effort succeeded so brilliantly. Generalizations are included on the steps McLean considered essential to the management of a successful design project for a new system, as well as project roadblocks likely to be encountered when the project is under government management. A subsequent version of this speech appeared as Chapter 15 in *Science, Technology, and Management*, Fremont E. Kast and James E. Rosenzweig, ed., McGraw Hill, 1962.

"Management of Research and Development," presentation at 15th Annual Industrial Engineering Institute, Berkeley and Los Angeles, California, 1 and 2 February 1963

McLean discusses the necessary steps in the R&D management process: (1) a vision of the desired objectives, (2) detailed, specific plans for the route to be followed, (3) motivation for the participants, and (4) a mechanism for evaluating how well the process has met its goals.

"The Art of Simple and Reliable Design," unknown source, Spring 1963
McLean knew from experience that "a simple design is anything but simple in its creation," and in this paper he states his principles of designing simple equipment, as well as his ideas about management of an excellent design team. He uses an example from the NOTS development of Ram (6.5-inch antitank aircraft rocket) to show how miscommunications can happen when several layers of management are involved.

(Invited talk by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California, to the Bendix Management Club, Los Angeles, California, 26 April 1962)

IS RESEARCH DIFFERENT

I have long been of the belief that research people react differently than other categories of people and that therefore the management of research organizations must be handled differently from other types of organizations. I recently came across an article by Rensis Likert, in the March issue of "International Science and Technology", which attracted my interest by agreeing with my views. Dr. Likert begins by listing the observations and results of an extensive program by the Institute for Social Research of the University of Michigan. These seem to be the kinds of things which a scientist takes for granted as being necessary for his effective performance. They include:

1. Good communications and mutual respect between members of the organization.

2. Frequent communication with colleagues from other fields and with those who have different methods of approach.

3. A high degree of self-confidence among the scientists so that they can maintain their independence of mind, even in the face of different opinions by their colleagues.

4. Scientists and engineers, who see their administrative chief often, perform rather better than those who do not.

5. A scientist seems to need a high degree of self-determination combined with free access to someone in authority.

It was encouraging to me to see that the results of social research agreed so closely with the criteria which I would set from my own experience as being the conditions which would lead me to the greatest productivity. Dr. Likert reaches a general conclusion which I would like to quote:

"Scientists and engineers are likely to be most creative when their supervision is such that they feel substantial freedom in their work--in selecting their problems and goals, in deciding on the approach to achievement, and in interpreting their data--and when they have frequent interaction with their superior. These findings are valid for the administration of basic research, developmental research, and engineering."

I believe that a conclusion of this type will find little objection from most working scientists and engineers. When these same scientists and engineers become managers, however, their problems in establishing these conditions for others become extreme. They are trained to believe that a classical organization is supposed to have a definite mission, with its progress planned and scheduled. In managing an organization, we should be able to establish a budget with definite milestones to check our progress against our rate of expenditures of funds. Can we work in a large organization and accomplish its definite goals if we leave each individual scientist and engineer freedom

to select his own individual problems and decide on his own approach to solutions?

As the head of a relatively large research and development organization, I feel these dual pressures strongly. I find that I have many ideas which I would like to have tried as a working scientist. I have very definite ideas about details of design for such ideas. I also have methods of approach to the solution of the problems which may be found to exist. I will have to confess that at the present time I have not found a satisfactory technique by which I can get the scientists and engineers in my organization to carry out my programs in the way that I would do them. Does this mean that the organization is a failure, or does it mean that I have failed as a manager to make my requests sufficiently explicit and direct? I do not believe that either alternative is true. I am simply caught in the position of trying to perform simultaneously two functions which are incompatible. As a scientist, when I have an idea and outline a specific design and program for carrying it through, I am performing a creative function which requires the freedom of choice, the responsibility for errors, and the necessity to carry the job through to completion, including the checking of data and correction of errors as they become apparent in the methods of approach. If I want to work as a project engineer, the organization will help me accomplish the goals which I have chosen. But my position as manager of the organization commands only slightly more assistance than any other project engineer and I have to continue to assume the responsibility for success or failure of the specific designs. Also, as a senior manager in the organization, there are some additional hazards to carrying a job through successfully because of the competitive position with other project engineers.

If, on the other hand, as a manager I want someone else to assume the responsibility for carrying through a specific problem, then I must get help from the organization at the early planning stage. I must find a man who will assume responsibility for each part. He must feel that he has the freedom to choose his program and that he is carrying it out along the lines which he believes are best. Any restriction of this freedom automatically frees him from the responsibility of making the final gadget work. In a large organization or project it is difficult to achieve the type of participative management required so that each man working on a part of the system feels complete personal responsibility for his piece of the whole program. He must have enough information and enough understanding of the goals of the total project to make his piece fit in the optimum manner. It is in accomplishing this general understanding that communications and mutual respect show their important influence on the total effectiveness of the organization.

The difficulty of maintaining effective communication with increasing size of an organization is the reason, I believe, that organizations tend to become less efficient as they become larger. Dr. R. B. Kershner of the Applied Physics Laboratory, Johns Hopkins University has written a very interesting paper on the optimum size of organization for any given job. He plots the time to accomplish a given objective against the number of people assigned to the task and shows that the curve has a minimum value. With too few people assigned, the job moves too slowly to maintain the interests of the people and their sense of accomplishment. As a result, a long time is required to finish the job. If the number of people is

increased beyond the optimum, competition for the jobs available becomes keen. Communications begin to fall off. The understanding of what is to be accomplished becomes more remote. The need for specific, definite specifications becomes greater. And finally, the ability of each engineer to participate in setting up the goals toward which he is working, and his contribution to the total design, becomes less with a resulting loss of interest. Tension within such an overstaffed organization grows, mistakes become more common, and the ability to try new things which might lead to significant short cuts becomes entirely too risky. The need for more coordination and more planning as the program lags becomes more apparent. The system is self-accelerating in that, as more coordinators are added, the engineers and scientists have less opportunity to provide feedback into the setting of specifications; thus, progress toward the final goal is further delayed. If we want to avoid these difficulties and have a participative type of operation, we should, as managers, try to do every job with an organization which is at the optimum, and this usually means the smallest size for its effective completion. If we increase beyond the optimum size, however, the forces become such as to automatically justify further increases in size.

How then can we tell whether we are on the high or the low side of the optimum organization? I have proposed that one technique which might be interesting to try would be to start each important program at levels separated by an order of magnitude. If we can justify the funds on the basis of the high level program, then the expenditures for the low level program will seem to be insignificant by comparison. I suspect that most of our military programs are now on the high side of the optimum expressed by Kershner's curve. If this is true, we should expect in many cases that a competitive program, working toward a given objective, which is funded at 10% of the present going program should have a reasonable probability of coming through in a shorter time and with a better final product. The product will be better because of the greater integration of the design which is possible in the smaller organization. The homogeneity of the small group, and the spirit of competition with the larger group will engender a group motivation which should lead to a high degree of creativi and cooperation.

All of these ideas for improving research or development organization, or for improving the working conditions of scientists and engineers, tend to become very controversial. We are continually faced with the question of determining whether any change we institute improves or degrades the organization, or the effectiveness of the individual. Dr. Likert suggests that as we become able to measure the improvements in an organization, by the periodic measurement of such things as employee attitudes, motivations, and the adequacy and accuracy of internal communications, we will gradually collect the data which will make it obvious that we should shift from what he calls the traditional management system over to the participative management technique. I believe that all of the specific measurement which he mentions, such as employee attitudes and motivations, or the accuracy of communications, can be grouped under one measurement which is relatively easy to make--the only defect in its general acceptance seems to be that it has an implication of frivolity. It is my conviction that all of the elements of an effective, creative, and productive organization can be measured under the single heading of a determination of whether the people making up this organization are enjoying themselves and

and are having fun doing their work. On the contrary, a poor organization is one in which fear is the guiding motivation and unhappiness with working conditions is apparent everywhere. It is, of course, possible to imagine situations which involve considerable enjoyment but very little productivity. I do not believe, however, that this type of operation can be maintained on a long term basis. I think it is the basic nature of man to enjoy being productive. His basic reasons for organizing are to increase his individual productivity. When the organization grows to the point where purely organizational goals become the dominant motivation, and man must serve the organization rather than have the organization provide the tools for man's creative expression of his desire to produce, then I believe we run the risk that the motivation of joy in achievement will be replaced by the motivation of fear of failure.

Dr. Likert concludes his paper by saying that their research suggests that all types of people will benefit from the same management required for engineers and scientists. Better management will concentrate on individual creativity of all kinds. This statement led me to my title--"Is Research Different." Is a participative management something which should apply only to scientists and engineers? As a technical man, I am sure that my productivity will vanish if I do not have such management, but as a compromise with the traditional theories of management, I am happy to sacrifice the rest of the organization to one way planning, rather than participation, if this will leave the technical work free. However, even in the Preamble to the Constitution we have a general statement that the largest organization, the Government, should be designed so as to provide the tools by which each man can achieve the expression of his goals to the limit of his ability. The opposite governmental system, in which the goals of the organization predominate and the man must subdue his individual interests and desires for the good of the total organization, is represented by the Communistic-type of society. It will lead eventually to a communal type of life which is well exemplified in its advanced forms by the bees and the ants. This type of organization can be very stable but it cannot achieve real adaptive progress because individual creativity has vanished for the good of the smoothly running organization.

I hope that we as a Nation can choose in the management of our businesses and our military programs the type of management which maximizes enjoyment, participation, and the contributions of individual creativity, rather than the type of management whose goals and objectives are set from the top and which is budgeted, planned, and integrated to achieve objectives on schedule without consideration of possible creative inputs. One type of management will strengthen what we have variously called "The Free Competitive System," "The American Way of Life," or "Life, Liberty, and the Pursuit of Happiness." The other type of management by overinsistence on the importance of budget and schedule, comes perilously close to conditioning us to the type of organization which believes that man's highest goal is to achieve and surpass through successive five and ten year plans.

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INTEGRATED FACILITIES FOR WEAPONS DEVELOPMENT

Presented at the Joint IRE-RTCA
Spring 1957 Meeting

by

Wm. B. McLean, Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

In considering the things concerning SIDEWINDER about which I might talk to you tonight, I found myself in what seems to be our usual security position of not being able to release as much about the weapon system as you have already read in the various newspapers and magazines. It therefore seems to me to be desirable to concentrate the remarks tonight on the organization which I feel has made the development of SIDEWINDER possible, rather than on the characteristics of the weapon itself.

When I was working at the National Bureau of Standards in Washington, D. C. during World War II, I always felt in the position of not having sufficient grasp of the various factors entering into the weapon system to really make an effective contribution. We were limited on one hand by the military specifications established by the Department of Defense, and on the other hand by the difficulties of accomplishing test operations after the first experimental models were completed. The second problem was complicated considerably by the fact that we usually spent weeks at Eglin or Dahlgren waiting for the weather to clear before we could get off the simplest tests of an explosive type equipment.

Near the end of the war I heard about the establishment of the Naval Ordnance Test Station located in the middle of the Mojave Desert where the sky was always clear. I understood the organization would be part of the Department of Defense and could influence the setting up of military specifications. I felt the opportunity for doing effective military development would be ideal under these conditions. During the past twelve years of operation at the Naval Ordnance Test Station, I have found the combination of the laboratory closely associated with testing facilities to be an ideal situation for the stimulation and carrying out of new techniques for ordnance equipment. I think you will all recognize that at the present time the military organization has a very difficult responsibility with regards to seeing that the country is properly equipped with the best possible weapons to fight a war or to prevent a war. This problem requires an intimate knowledge of such a large number of technical possibilities that it is very difficult for any one person to achieve sufficient breadth of understanding.

Good design represents a process involving a continuous series of compromises among the military requirements, research and developmental possibilities, good engineering practice, and operability in the field. I am sure you are all familiar with the fact that the development man always considers the research man impractical, and the engineering and production man wishes the development people would be more concerned with the problems of production, and, as the system proceeds into test, the testing personnel cannot understand why the equipment cannot be made more reliable, and, finally, when it gets into service use it is always too complicated. The Naval Ordnance Test Station is organized on such a basis that this type of complaint can readily feed back between the various groups concerned. By living and working together, the operational military man, the research, development, engineering, and test personnel are all mutually able to influence each other and, we believe, all generate broader points of view. As the understanding of each other's problem grows, we believe the design compromises will be more carefully evaluated and better overall specifications and designs will result.

I do not believe that in the field of ordnance very many organizations, such as the Naval Ordnance Test Station, can be established due to the large requirements in both facilities and territory. It is therefore incumbent on us to make our influence as widespread as possible. We want to keep our workload confined to those problems which generally would represent a high risk to any industrial organization due to the lack of reasonable and specific specifications. It is in this area that the quick interplay of research, design, and test, and their influence on requirements can be most fruitful. We believe that the end process of our operations can be a reasonable and workable specification which can be turned over to industrial organizations for production at a much lower cost than might otherwise be involved.

We are gradually becoming aware of the widespread effect which can be achieved through the training of people. The broadening of viewpoints produced in both military officers and civilian scientists will remain effective as they proceed to other assignments. The military man moves on to such jobs on a regular schedule. I am sure that the whole industry represented here tonight has experienced the fact that, while not as regularly scheduled, the movement of scientific manpower in the civilian areas can be as rapid, particularly under the competitive conditions existing in the Los Angeles area. We feel that this movement can work considerable hardship in particular cases; however, in our case we should not consider it a total loss because through it we can contribute to better understanding of military problems in industrial organizations. In fact, we have considered that as people leave the Naval Ordnance Test Station we should perhaps provide them with a degree in ordnance science as recognition of their completion of a period of study of the many problems enter-into the design of military equipment.

I would now like to show you some pictures of our operations at the Naval Ordnance Test Station together with some firing sequences showing SIDEWINDER in fleet use. I have also picked out some pictures of flutter tests on the SNORT track which I believe will be of particular interest to this group. Following this, we will have the story of the development of the DART tow target which, while it represents a very simple development program, illustrates very well the kinds of interchange which occur in all of our projects between the testing operations and further research and design.

"RESEARCH AND DEVELOPMENT OF MILITARY EQUIPMENT"

by

WM. B. McLEAN, Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

(Invited lecture presented at the University of California, Berkeley, California, 17 April 1959, sponsored by the Engineering Lecture Committee, Department of Engineering.)

I have been asked to speak to you tonight about the problems of coordinating an engineering program in the research and development of military equipment.

In my opinion, a good engineering design is more of an art than it is a science in spite of the great emphasis which we have on technical calculations and on the improvement of engineering graphs and curves. It is an art primarily because the number of possibilities for a successful solution to a design problem becomes continually greater as our knowledge of equipments and techniques expands. The proper selection among these techniques is something which becomes more difficult to establish on a rigorous and rational basis the greater our knowledge of techniques and processes. I believe the failure to recognize the need for artistic choices in the design process is at the root of many of our management problems in our more complicated programs. We believe that because our scientific calculations are exact, the process of choice can also be exact.

The normal process used to accomplish a design, such as an intercontinental ballistic missile, is to authorize a contract and establish design specifications. A planned program with a fixed budget is needed before a man can even begin to think. From this point on, the imagination of the designer is limited and he feels it is his responsibility to meet these specifications even though minor changes would result in a much more effective overall design. It seems to me that the creation of a missile system would progress more effectively if it were recognized to have many of the same problems as the creation of a large mural painting. Many useful analogies might then result. The creation of a mural is obviously too large a job for one man and yet, at the same time, it must represent an integrated whole, rather than a collection of parts. In the case of the mural, we have adopted the practice of selecting a master artist whose responsibility is to conceive a picture in accord with the general message which is to be conveyed. He then uses his imagination, his understanding of the materials and tools available, and his knowledge of the abilities of his assistants to lay out an overall

Design. Committees can review his work and make suggestions, but they cannot take over his responsibility for it. Once the general concept has been sketched out, many people can begin to work using their own specific abilities to fill in the various parts of the picture. As a result, we have an integrated created that reflects primarily the skill, ability, and experience of the master artist, but which also uses the individual skills of his assistants to a maximum.

It appears to me that this same technique should be applied in the design of a missile system. We know generally what it should accomplish. We should select one man of demonstrated experience and ability in the field to conceive and layout the work necessary in the various component areas. These areas can then be filled in and, if proper coordination is maintained, the whole picture can be redirected and reoriented to achieve a better final result as limitations in some areas and advantages in other areas become more clear. I become exceedingly skeptical whenever I hear the phrase that "amissile is to be composed entirely of off-the-shelf items". I feel this design will probably have the same structural strength and beauty of conception that would be represented by a montage of photographs for the production of a mural painting. It may result in a masterpiece, but the probability is not high.

An important difficulty in the missile design area is that the progress of science has been so rapid that people have been forced to specialize and, as a result, designers with the breadth of background sufficient to handle a complete missile are almost non-existent. This leads to design by committee with the final product clearly showing the lumpy structure representing individual enthusiasms. In addition to covering fields of specialization, I believe our educational program should institute a process which will select a group of people with a high degree of imagination and the ability to comprehend a large variety of different areas, and institute a training program which will give them the range of skills required to undertake broad designs, such as a complete missile system. These people should understand, for a missile, such things as chemistry and propulsion, explosives, fuzing, power supplies (both battery and generator), hydraulic, electric, and pneumatic controls, aerodynamics, gyrodynamics, electronics, transistors, magnetic amplifiers, psychology and physiology, astronautics, and most importantly, be the victims of an all-inclusive curiosity. The emphasis in this type of training should be an understanding of the basic principles which, at present, limit our progress in any given direction. The details of calculations after the basic formulations are understood can well be left to machines or those people more interested in the limited areas. A course in the basic vocabularies of the many technical dialects would be valuable to these people who must converse intelligently in many fields.

I am sure it is obvious that we have very few people who can qualify as master designers for a missile system. The time required for one man to comprehend all the problems involved in a complete system will severely limit the rate of progress which is needed and the size of the overall program which can be undertaken. Because of these limitations, I am sure that we will always be faced with the problem of wanting to get equipment more rapidly than is possible. Therefore, we will always be forced to establish well planned "crash" programs involving the maximum rate of progress con-

sistent with the techniques and technologies currently available. I feel strongly, however, that each such program should be accompanied by a small, artistic, and, perhaps, underfunded program which will look for the elegant solution rather than the obvious solution. The funding of such a program should not exceed 5% of the crash program in order to prevent the kind of rigidity which sets in as soon as a program is pushed at such a high rate that feedback between the groups working on various parts is hampered. I suspect that such a program will not only save money but many times will come out ahead of the more massive program.

The Naval Ordnance Test Station is one of the organizations in the country which feels itself well-equipped to handle this artistic type of engineering design. We have the people and equipment necessary to investigate basic research problems, do development and development testing, do experimental production and testing, and have direct contact with the using services. Since we are part of the Navy organization, we are able to treat military design specifications with considerably more flexibility than is possible in a commercial organization working on a wepon design contract. We have a very diverse group of people, running all the way from basic research scientists to operating military personnel, living in a community of about 12,000 people. This type of community life, which promotes the rapid exchange of technical information, generates the kinds of radically new ideas which result from the cross-breeding of the ideas of people with basically different backgrounds. Because we are close to facilities for testing these ideas in either the laboratory or on the ranges and have the tools available to construct the hardware necessary for these tests, we have at hand the machanism to rapidly sort out the most useful ideas.

I have with me a movie entitled "Expanding Frontiers in Ordnance" which shows some of our facilities and illustrates the variety of skills and techniques which we have available for incorporation into the design of new military devices. At the conclusion of the film, I will be happy to answer any questions you might have.

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UNITED STATES CIVIL SERVICE COMMISSION

D I G E S T O F P R O C E E D I N G S

of the

I N S T I T U T E

FOR

CAREER SCIENCE EXECUTIVES

October 12 - 20, 1960

Stone House
National Institutes of Health
Bethesda, Maryland

FOREWORD

The Institute for Career Science Executives was designed to promote the effectiveness of Federal scientist-executives through the study of important concepts and current issues relating to the organization and administration of scientific and related activities of the Federal Government.

These summaries were prepared by the participants and represent their views of the most significant points made by the speakers.

Charles A. Ullmann, Director
Management Institutes
U.S. Civil Service Commission

Summary of Panel Discussion
On
EVALUATION AND MANAGEMENT OF SCIENTIFIC PROPOSALS

Members of Panel: Mr. James F. Kelly
Director
Office of Financial Management
Department of Health, Education, and Welfare

Mr. Willis H. Shapley
Chief, Air Force Section
Military Division
Bureau of the Budget

Dr. William B. McLean
Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

Mr. DeMarquis Wyatt
Technical Assistant to Director of Space Flight Development
National Aeronautics and Space Administration

ecording Team: Dr. A. F. Bartsch, Dr. Jacob E. Dinger, Mr. Richard G. Grassy, and Mr. William Luzerne Lovejoy

The question "How does a program administrator keep his research people working n questions to which we will need to have program answers?", sometimes seems a prob em because the scientist is motivated to slant the proposal for a research program long lines which may best "sell" the idea. This may be different from his true interests and the exact approach he ends up pursuing. The more persons who pass on a roposal, the more unlikely a novel idea will be accepted. In setting up a basic research program, emphasis should be on selecting good research people and not so much n proposals. A formula for generating good basic research is: "Pick a good man, ay him for life, then support him with funds on that research in which he is willing o invest some of his own financial resources." This formula has the ingredient of upporting research in which the man is sufficiently enthusiastic to venture some personal risk. One example of such risk is his putting his reputation on the line when acking certain research.

The lines of effort to be followed by an organization is often considered an dministrative matter—outside the initiative and freedom of the scientist. Every ctivity obviously has a mission. Short of establishment of a Federal "Institute for esearch", Government organizations are established to carry out missions not directed rimarily at conduct of general research. The scientists' choice of research area herefore academic, and imposition of controls to insure compatability of research ith agency mission is the function of administration. It is necessary to consider he people who will do the actual work. Evaluation of their proposals for research ill include, as a primary factor, consideration of their qualifications—principally

their prior work. Such evaluations are best made at lower management levels, close to the men and the work.

Many of the administrative problems of keeping the program in line with the agency mission can be solved or avoided by inculcation of a team spirit oriented toward solution of agency problems. Development of such a spirit, and the leading of individualists along lines beneficial to the agency, are the responsibility of management.

Basically the issue of keeping the researcher working toward needed program answers is a problem of how to work with people. This problem occurs in all fields, but research does have some unique problems of its own. A notable one is failure of communications between the researcher and management. The objective in hiring the man, which must be related to the mission, is not always clearly emphasized. Tangential interests of the scientist sometimes lure him away from the mission.

Insofar as basic research is concerned, once a program has been chosen by management, little detailed direction should be provided. The individual scientist should be given free rein to attack the matter in the way he considers best. Even in basic research, however, complete freedom may not be entirely justified. The very selection of the program to be undertaken removes, to some extent, the "free rein" atmosphere. There must be a motivation toward some goal, and in many cases there must be a reason given which permits the scientist to rationalize directing his talents to the program. For example, scientists working on the Manhattan Project often asked themselves later, "Was my participation in this project morally justified?" To answer such questions, national goals or needs, such as national security, must be crystalliz in meaningful terms. Here management must take a part and must draw upon the talents and thinking of those normally considered as being outside the scientific community.

In applied research, the problem is quite different. Here the goals are much more narrow and specific; they are formulated at a lower level, and they must be closely adhered to if the project is to be a success. The limits of freedom of action must be much narrower, but still the scientist must be allowed some latitude in which to exercise his own judgment. Management must achieve a situation where effort is channelled without stifling initiative and independent thinking.

As an interesting sidelight, the policy of the Bell Telephone Lab, as imparted to new employees, is "You are free to work on anything, but remember that we are in the telephone business."

Basic research and development in the same institution is a desirable thing. People are all different, and a wide spectrum of activity permits a greater opportunity for a given individual to find himself.

When basic research is separated from applied research, as in all living creatures, each part tries to grow back the missing part. Basic policy of NASA is, however, that research and development should not be intermingled. A key factor is the tendency of the best scientists and engineers to migrate, voluntarily or involuntarily, into the development programs. This policy has not been entirely satisfactory because personal interests are not satisfied, and the cross-fertilization of research and development ideas is stifled. At the jet propulsion laboratory, a middle-course has been adopted; basic research of up to 25% of manpower available is

supported with technical program content controlled by the laboratory, subject to headquarters review.

The question of mixing basic and applied research in the same organization is one to which no hard and fast answer seems to be possible. It has been suggested as desirable that the individuals who generate a basic concept carry it through to the developmental stage, thus providing desirable continuity and insuring that the usefulness of the basic concept is fully exploited in a timely fashion. But this poses serious problems. Much time and effort can be expended in the "tooling up" and reorganization of an organization devoted to basic research to carry on applied and developmental research. There is also the problem of disposition of the developmental portion of the organization when the developmental work has been completed. Serious personnel adjustments may be necessary.

The universities apparently do not look favorably on mixing basic and applied research, and complain that the Government's insistence that they accept developmental contracts is seriously diluting or even eliminating their ability to do basic research. The universities seem to regard basic research as their proper sphere of operation.

Probably the most effective control of scientific research is maintained at the budget decision level. Here decisions are made as to where funds shall be spent and how much will be allotted. These decisions really mold, in a large degree, the course of future research. From that point on, decisions are largely confined to how the goals can best be achieved with the funds available. For example, the need to continue and expand basic research is well recognized generally. The questions to be resolved are where and how much. Top level management of a "heads-up" variety is required to recognize areas where research may provide a big pay-off and to provide flexibility that will permit the pursuit of this research. This flexibility must also apply to funding. One approach is represented by the DOD Emergency Fund which permits $150,000,000 to be used to exploit unforeseen opportunities which may arise. Here, "playing the hunch" becomes important, and environment has a great bearing on this. For example, where a considerable investment has already been made, the question of playing "hunches" assumes an aspect different from that which existed when the original investment was made. However, the basic questions to be answered are essentially the same, i.e., how important is it, and how much are you willing to risk. Another aspect of environment is the nature of the climate within which an agency operates. Some are much more research oriented than others and give a more favorable outlook.

THE SIDEWINDER MISSILE PROGRAM

by

WM. B. McLEAN
Technical Director

U. S. NAVAL ORDNANCE TEST STATION
China Lake, California

Presented at the National Advanced-Technology Management Conference held in Seattle, Washington, 4-7 September 1962

Presented at the National Advanced-Technology Management Conference, 5 September 1962, Seattle, Washington

The SIDEWINDER Missile Program - Wm. B. McLean, Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

Ladies and Gentlemen:

When I was placed on the program immediately following Admiral Raborn and Dr. Burris speaking on POLARIS, I am sure it was more for the purpose of providing contrast, rather than to group similar programs. SIDEWINDER and POLARIS are certainly quite different--in size of the job, the amount of money involved, and in the kinds of management techniques employed. In the presence of this company, I have some of the feelings of the longhaired artist, who paints just for the fun of it, attending a conference to discuss the techniques of commercial advertising art. We were not commissioned to design SIDEWINDER; we had no externally imposed specifications; and we started with no timescales other than those imposed by competition. Our prime motivation was to avoid the construction of the Aircraft Fire Control System Mk8 whose purpose was to fire unguided air-to-air rockets. This system we felt would produce an inferior result compared to a properly designed homing missile. We felt we had an inspiration with regard to a method of approach to such a missile design which would be fun and a challenge. We also believed there was a good chance that this missile could be made to work as simply and more effectively than the fire control system for unguided rockets.

Although designing missiles was new for our group, we did have some pertinent background experience. I had been associated with the problems of packaging electronic equipment in a small space, and the requirements for high reliability and producibility, through working on the VT fuze programs during World War II. I also had an early introduction to the problems of missile control by acting as a consultant on the design of some gyros and actuation systems for the BAT missile when it was being developed by MIT and the Bureau of Standards. From 1943 until 1948, I was working with a group trying to improve the sighting systems for air-launched rockets. Our first problem was to localize the major source of error: pilot, computer, aircraft, or target motion. In the course of this study we developed ranges and range techniques and acquired a deeper appreciation of what pilots, aircraft, and aircraft crews could be expected to do as well as the things which they probably would not be able to do. Since our fire control system was also to provide for the firing of missiles, we were able to visit many of the activities engaged in the design of missiles at that time. This included the German V2 scientists at White Sands the Hermes people at GE; the SPARROW organization at Sperry; the METEOR work at MIT; the BUMBLEBEE group at the Applied Physics Laboratory, Johns Hopkins University; the DOVE work at Eastman Kodak; and the FALCON work at Hughes Aircraft. We owe all these programs a debt of gratitude because at each place we discussec the relative merits of unguided rockets versus the problems of missiles and collected data on the difficulties which each organization was encountering in the design of their specific missiles program.

By 1948, we had achieved good measurements of all of the contributing errors for unguided rockets launched from aircraft. Our results showed that such rockets can be made very effective against non-maneuvering targets. Nevertheless, if the target makes an unpredictable maneuver after the rocket has been fired, the flight time of the rocket is usually so great that the unpredictable target motion after firing can produce an error more than three times greater than the sum of all other contributing errors. We also learned a great deal about the difficulties of keeping electronic equipment operating in an aircraft. The only good answer to the air-to-air problem seemed to us to be a guided missile which could solve the fire control problems as it progressed. Also, if we could keep most of the fire control circuitry in the missile, the maintenance of the fire control system would be solved, at least in wartime, by shooting it.

Unfortunately, we reached this decision at a time (1948) when the anti-missile sentiment in the country was very high. There was great disappointment in the fact that the missile programs were progressing so slowly and that they were so expensive. Great effort was being expended to cut back on missile developments. Everytime we mentioned the desirability of shifting from unguided rockets to a guided missile, we ran into some variant of the following list of missile deficiencies:

1. Missiles are prohibitively expensive. It will never be possible to procure them in sufficient quantities to use them in combat.

2. Missiles will be impossible to maintain in the field due to their complexity and tremendous requirements for trained personnel.

3. The prefiring preparations, such as warm-up time and gain settings required for missiles, are not compatible with the targets of surprise and opportunity which are normally encountered in air-to-air and air-to-ground combat.

4. The fire control systems required for the launching of missiles are complex, or more complex, than those required for unguided rockets. No problems are solved by adding a fire control computer in the missile itself.

5. Guided Missiles are too large and cannot be used on existing aircraft. The requirement for special missile aircraft will always result in most of the aircraft firing unguided rockets.

This series of objections, expressed many times and in a multitude of variations for the purpose of keeping us out of the missile development operation, constituted our design objectives for the SIDEWINDER system. Many hours of thought and discussion were required before we finally felt we had a design with some chance of being acceptable to the people who were not in favor of guided missiles. Therefore, one of the major differences in the SIDEWINDER program, compared to other missile programs, was that it was designed to please people who in general were <u>against</u> such systems, rather than the people who were in <u>favor</u> of them.

I suspect that we might find here a general management principle which is that a statement of the problems or the objections to an existing system will produce a more creative approach to the design of a new system than will be achieved by a set of definitive specifications for the new system. Valid objections leave many approaches open. Specifications tend to channelize thinking along the lines of a single approach.

The design we originally proposed for SIDEWINDER, in order to meet the existing objections to missiles, had many elements which had not been tested at that time, such as torque balance control on the canard wings, rollerons for roll stability, a propellant-driven power supply, a hot gas servo, and a gyro tracking system which was independent of roll rate. If the SIDEWINDER missile had been a crash program, any one of these elements would have been too risky to include in a system which had the need to proceed on schedule. Since the management pressures on SIDEWINDER were, at most, permissive, we had the opportunity to carry out feasibility tests on the various critical components before proceeding with a complete missile assembly.

We might have fallen into the trap which is quite common for low pressure programs of never finishing the feasibility studies by always seeing the opportunity for improvement. If one becomes so trapped, a final design will never result. The SIDEWINDER program very fortunately, in addition to having a permissive atmosphere from our immediate supervisors, also had a strong active opposition from some of the higher levels of management. About every three months we had a committee of experts to investigate one of the critical areas in the design to see if this area was not sufficiently shaky to merit cancellation of the whole program. This provided a powerful incentive to our group to complete the feasibility investigations and come up with a firm,proven and field tested design in each critical area prior to the arrival of each group of specialists.

By 1953 we had our first successful shot, and by 1956 the missile was in production and was seeing service use by the fleet. The missile was successful in that it avoided most of the original objections to its use in combat situations which were given by the antimissile people. Now SIDEWINDER has been accepted for service use and has even been used under rather unusual combat conditions by foreign services with a minimum of training time.

MANAGEMENT TECHNIQUES

Now that I have said a few words about the initial conception of SIDEWINDER, and something about its history, I will proceed to the things which are more pertinent to this conference; that is, the techniques by which the program was managed. The management of SIDEWINDER was relatively easy because of the organizational setup. We had a rather small number of good people who were highly dedicated to getting the job done and who worked closely together so that they had a good appreciation of the over-all problems. They had immediately available all of the tools needed to do a complete job, from basic research through testing plus continued contacts with fleet personnel as to which techniques were most likely to be acceptable by the people who would be using the equipment.

Communications were facilitated by the fact that the working group was isolated in a small community in the desert about 150 miles from the nearest large city. People could and did communicate with each other all day, through the cocktail hour, and for as long as the parties lasted at night. This isolation in a location where the job could be performed provided large measures of the intimate communication which is so essential for getting any major job completed. In all honesty, however, I will have to report that this particular technique for communication generates some family strains and pressures. The wives tend to be less enthusiastic about continuous attention to the work than the men.

In looking back over the program, the single most important abstraction I would draw is with regard to the importance of not starting too fast. At the start of the SIDEWINDER program, I personally spent nearly three years on a part-time basis in the process of considering possibilities--mentally arranging them into a missile, checking the tradeoffs, and trying to think of other methods of arrangement which would make the final design more acceptable to the user. At this stage of the development, reorientation of the program is easy. A complete reorganization of the internal workings of the missile can be accomplished literally in the time that is required to think of it. I believe that this process, by which one man gets fairly clearly in mind a picture of what he would like to produce and the reasons for selecting one set from a multitude of possible choices, is a very important step in the accomplishment of a satisfactory final product. This man must perform very much the same functions as an architect in the construction of a building. In our present method of budgeting funds, the function of this man is quite frequently lost. If he ever did exist at the planning stage, he will almost certainly be lost before the project reaches the stage where the completed design must be put down on paper.

As the SIDEWINDER design was committed to paper, we began to lose flexibility, and the critical elements of the design became apparent. The need for both the construction of test hardware and the carrying out of critical tests grew, and with this growth the organization increased in size. Timescales became interdependent, and at least informal schedules for the various parts of the program had to be made in order to allow people to work on their particular parts of the program independently. We were very fortunate in not having to build the complete design as an entity and send it away to another organization for test. We were able to construct crucial parts of the system and test them directly before going on to the more complicated parts. We were fortunate in having a relatively small group of engineers working together on pieces of hardware that were carried through all of the stages from design to final test. This provided a very important experience in training them not to overlook necessary elements when the tests became more complicated and the organization larger.

During the slow starting period the small group was able to establish their own goals. Good technical people like to believe that they are doing their own planning. This becomes increasingly difficult as the size of the organization increases. They begin to see that they are caught in someone else's plans and, as a result, they may lose the high degree of self-confidence

and initiative which are perhaps at the root of the successes which have distinguished them as outstanding people.

Before the first successful shot was completed, we had between 250 and 300 people working on the project at the Naval Ordnance Test Station. We were monitoring work of at least four other government installations, as well as the prime guidance contractor and about ten or twelve other industrial organizations. We found it necessary to hold quarterly and then monthly meetings with representatives from all of the groups working on the project. These meetings quite often generated lots of heat and very little light. The resistance to change increased remarkably. The differences of opinion would never have been resolved if it had not been for the experience of the original, small integrated group that was familiar with the process of taking things out for test. Theoretical arguments and calculations will resolve many problems; however, Mother Nature, if asked questions in the right form, performs an arbitration function on the test ranges which is beautiful in its conclusiveness.

I am sure you are all familiar with the difficulties of making changes when 1,000 or more detailed drawings are involved, and with the inertia of a production line set up with programmed belts and assembly fixtures for all of its people. At this point, the design is finished, and creativity in design had better be saved for the next project. The maximum use of creativity must be confined to making the machine work with the fewest possible changes in any of the parts. We were fortunate in having a design that could be produced with only minor changes. If this were found not to be true and if the basic design were found to be unsound, then time would probably be saved by scrapping the whole program and starting over. However, the investment up to this point is usually too great to permit this solution. We usually compromise on a less than optimum design and shift our responsibilities to fleet maintenance and operation.

Let me review what I believe to be the important steps in the management of a successful design project for a new system. First, I believe it is essential to have a man who can visualize in some detail what he would like to create and who has carefully thought through the problems associated with the creation of his system. He will perform, with respect to his design, much the same functions which an architect performs in the design of a complete structure. Second, The designer, or architect, needs to interpret his vision of the complete system by sketches and rough drawings which can be used by other engineers and technical people to do more detailed design and construction of the parts so that they will fit into an integrated whole. Each of the additional people must understand the complete design and must communicate frequently with the architect to be sure that the parts fit properly into the whole system. Third, the organization can be expanded and the production of subsystems for test and evaluation can proceed. While this is in progress, the man in charge should make frequent visits to check on all of the components to see if they are progressing in the way in which he had visualized them and that they will not distort the final product. He also must perform the function of rejuggling the compromises as some parts of the system become easier, and other parts become more difficult.

Finally, the components are assembled into a working and tested model of the complete system. Here we reach the first point at which the services of the master designer, or architect, might be dispensed with and his design turned over to others for production. Such a shift becomes possible at this point, but is usually not desirable. Most designers would like to continue contact throughout production, although their interest will decline as the problems disappear.

MILITARY DESIGN AS A SPECIAL CASE

Are there elements in our present government management system which tend to prevent this logical prosecution of a project by picking a man, letting him think through a problem, test the areas he finds critical, construct and test a prototype, and finally, put the prototype into production? I think there are several.

The first roadblock in this process appears to come from our inability to pick a designer. This choice has some of the same pitfalls inherent in choosing a man to do any other form of artistic endeavor, such as architecture, painting, or composing music. The creative man in any field tends to be more interested in the process of creation than he is in the monetary rewards which may result from this process. In fact, it is only through the use, not the creation, of a creative product that any large monetary return can be realized. Artists tend to be more concerned about creation of something new than they are about its eventual use. Artists, such as painters, musicians, and sculptors can usually express their ideas with very little investment in tools or capital equipment. The opportunity for self expression is therefore available in these fields to any number of people who have the urge to try them without the concurrent need for immediate use and profit. Large numbers of people can try these forms of art, and we learn to judge the best and discard the rest. Creative technical design, however, involves a considerably higher expenditure of funds and we therefore feel much more compulsion to carry out this process in such a way that it will always be successful and show a net profit. The number of creative designers who can compete on a directly comparative basis is therefore extremely limited. Therefore, the number of art critics who have been developed that are capable of judging creative designers is almost non-existent. We need to find a technique by which more unrecognized creative designers can test their skill and develop their talents without the danger of complete and disastrous failure, both to themselves and their associates. We need also the skill to recognize that a design may be poor even though it works.

The second government management problem comes in providing protection to our selected designer so that he can think through his problem and exercise his creative talent prior to being committed to a course of action. The mechanism in government for the establishment of a budget, and shepherding it through uncounted discussions on relative priorities, tends to draw a go-no-go line with respect to every project. A project is worthless and not meriting of any support until it is possible to build up enough arguments for its merit, and enough information on its need, that it crosses the threshhold of recognition and its accomplishment suddenly becomes a national emergency. In the crash activity

which results, the men who have been spending the time thinking the problem through have either become discouraged and started a new project, or they are forgotten in the confusion which accompanies the initiation of a crash program. The time to think is at a minimum in crash programs.

A third management problem which prevents the orderly progress of a development is the degree of commitment to a design which is inherent in our governmental approval process. When any project breaks over the threshhold required to get sufficient attention in the budgetary process, a rush request goes out, formally and informally, to 50 or 100 organizations to complete a design competition with a deadline ofperhaps two weeks. The design proposal must carry with it not only the detailed method of approach, but also a time schedule and a budget. Any of us who have been through the process know that this degree of commitment to design, time, and budget makes it very embarrassing to change the design. Change is difficult even when test of the critical elements shows that the original concept was unworkable. It is even more difficult to make changes which are purely for the purpose of improving the esthetic appeal. In fact, I imagine that even mentioning the possibility that a design should have esthetic appeal will cause some people to think that I am completely impractical.

The final government management problem lies in the need to skip an orderly development process when carrying out a crash program. We finally convince ourselves that a program is sufficiently urgent to get started and we now must, of necessity, complete it in the minimum conceivable time. This means that there will obviously be no time for the construction and test of a prototype. We must run the calculated risk of initiating the procurement of long lead time items, and the final design will thus be biased in order to use them. We must start the construction of our test ranges and our production facilities while our design is still struggling to be born. Since specifications for ranges and production facilities are easy to write, their construction will proceed rapidly, and their completion may determine what can be tested or produced.

It is easy to state what is required for good management of a program, and it is equally easy to see that these elements will be difficult to achieve in a real political atmosphere. What we need is the invention of a management process which will satisfy the competing technical and political requirements. I would like to propose such an invention for your consideration.

Dr. Kershner of the Applied Physics Laboratory, Johns Hopkins University has written a very provocative paper[1] which has laid the ground work for this proposed management invention. Dr. Kershner points out that for every project there is an optimum size organization. He postulates that if we plot the time necessary to accomplish a job, versus the number of people employed on the job, we will find that this curve will at some point have a minimum

1. R. B. Kershner, "The Size of Research and Engineering Teams," in <u>The Proceedings of the Eleventh National Conference on Administration of Research</u>, Penn State University Press, September 1957, pp. 77-83.

value in the time required to accomplish the job. Determination of the number of people representing the minimum value for different kinds of projects is the manager's dilemma. His job is particularly complicated by the fact that, at every point on the curve, all the people involved in any project believe that the organization is too small. In fact, as the working force passes the minimum point on the curve, and the rate of progress begins to drop, the perceived need for more people and more liaison increases rapidly. And, as Dr. Kershner points out, more engineers on the project can invent more avenues of approach, and more techniques to try. The maintenance of coordination between all of these different possibilities becomes a function which again requires more people and more paper work.

I would propose that the determination of the minimum size organization for any particular job is a problem which can only be accomplished by an experimental approach. When we are working in well-travelled areas, such as producing new models of automobiles or constructing houses, we have established norms which serve as guides on future jobs. Or if we have a competitive operation, then the fact of competition will in time bring the size of the organization to its optimum value. In the development of new military equipment, we need a substitute for standard norms or for the operation of a competitive process.

I believe that such a management technique can be accomplished if, for every military program started in an area of work where standards are not available, we set up two competing approaches which are separated in funding or manpower by an order of magnitude. I am not prepared to argue that this is the best separation. Any other separation would also provide the kind of data which we are seeking. However, I believe that on most of our military programs our departure from the optimum size organization may be in error by at least an order of magnitude. Any smaller separation of the two programs is therefore not likely to produce results with the maximum observable difference which will make it easy to determine the slope of our curve and, therefore, our position on it.

In operation, whenever we are forced by political pressures to start a crash program, we should select a prime contractor and start funding him at whatever level seems politically expedient. We should then survey the remaining people and find those who believe that they have a technical idea which is sufficiently novel to allow them to have a reasonable expectation of competing with the prime contractor at a cost which is one-tenth the one at which he is actually funded. An important element of this process is the necessity of maintaining the ratio between the two projects as they progress. Neither project really has a good appreciation of the technical difficulties which will be encountered if the work is in a really new area. Both will feel that additional funding is essential. However, our management techniques should be quite rigid in maintaining a fixed ratio between the two programs no matter what arguments for additional funding may arise. I think you can probably see that one of the effects of maintaining this ratio inviolate will be to put most of the burden for justifying additional funding on the program which is proceeding with too much manpower. This will improve total net progress by providing jobs for the excess people.

If both programs actually lie beyond the optimum number of people for the most efficient accomplishment of the job, then the ten percent program will be making the higher rate of progress. We will have automatically built into the system the management tools required to keep the crash program from expanding in a disastrous manner.

If we are able to attain the very desirable condition in which the ten percent program is just slightly smaller than the optimum manpower or funding level, then I suspect that the condition can arise where both programs will be observed to be making approximately equal progress. At this point, I suspect that it will take all of our persuasiveness as managers to convince the budget analysts that it is essential to continue the program funded at the high level. Its function as a tool to shield the low-funded program from the political pressures and military requirements will be hard to explain. However, without this protection, the low-funded program will be unable to take the high risk ventures which are essential if our accomplishments are to be great compared to our effort. We need both types of program in order to be able to achieve real technical progress in a framework of a real political environment.

In essence, my proposal for the management of military programs is to attack each objective with both a large program, which will provide a safe, scheduled and well funded route toward the objectives, and a more risky venture funded at ten percent of the cost where we can try out the talents of our creative designers without forcing them to risk the political safety of the nation while they are taking chances.

I believe that SIDEWINDER was such a ten percent program, and that it owes a large measure of its success to the shield provided it from political pressures by its competitors, FALCON, METEOR, and SPARROW.

I believe that SIDEWINDER was produced in a nearly ideal management setting and that the only defects I can find in this management system would be rectified if this type of program were to be (a) recognized as a management device, and (b) funded at the ten percent level without the need for wasting time on justifications for more money.

If such a management tool is ever accepted, I personally hope that I can always find an opportunity to work on the ten percent end of the programs where the creative technical approaches sometimes will have the high payoff, rather than on the on hundred percent end where the prime emphasis must be on setting and meeting schedules imposed because we live in a real world with real political needs.

Both types of program are essential and the people exist who will believe in and enjoy one or the other approach. The competition between the programs should provide valuable incentives for both groups, always resulting in reduced total costs and sometimes with exceptional products when a risky and creative venture succeeds.

Thank you.

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MANAGEMENT OF RESEARCH AND DEVELOPMENT

by

Wm. B. McLean
Technical Director

Management in the broad sense is the process by which raw materials, men, and machines are organized to achieve an objective. For the accomplishment of the management process, we need, first, a vision of the objective to be achieved; second, detailed planes concerning the route, or routes, to be followed in reaching the objective; third, individual motivations for the people concerned which may or may not be related to the objective to be achieved; and lastly, we need a mechanism for evaluation which will tell us how well our management process has succeeded in achieving its goals.

SETTING OBJECTIVES

The manager in setting the objectives for his organization performs his most difficult and important function. In a completely planned society he might write in to the central planning authority and receive a copy of the mission for his organization with enough detail to relieve him of the goal-setting responsibility and allow him to proceed directly to plans. However, most of us would probably object to this procedure. We have an intuitive feeling that we want to set our own objectives without too specific guidelines and we would like to be judged by competition. This is the basic process in a free competitive system such as capitalism. It has only very broad general objectives, such as producing more goods, and each individual organizational entity can set its own local objectives and procedures to further the general goal. Our abilities to satisy society's needs are judged by competition and rewarded by success or failure. This process provides high incentives and high motivation. People work best when they feel they have set their own objectives. The general management can be very loose and competition provides opportunities both to try and to judge all sorts of organizational procedures.

Paradoxically, this system seems to generate problems for itself merely because it becomes so successful that it satisfies all of our needs. At this point we are tempted to fall back on more centralized planning and more narrow definition of mission in order to control our output, rather than to undertake the more difficult task of broadening our objectives and increasing our needs so that competition can still have room to operate.

A similar paradox seems to operate also in Research and Military development. Here, too, the competitive system seems to function in such a manner as to overproduce and generate the need for more control. In Research we set a general goal of understanding the operation of Nature. Such an objective allows freedom for each research man to define his own areas of interest. Competition again provides a general management function as long as all the individuals can understand what the others are doing and can judge their own rate of progress relative to that of others. We

again have a breakdown when the rate of progress exceeds our ability to absorb, and we have duplication through ignorance. This is obviously a waste and the demands for centralized planning come to the front. Again, we have a choice between broadening our ability to consume by discovering better methods for transmitting and absorbing information, or we can choose to limit production by instituting centralized planning as a substitute for individual goals.

In the planning of military equipment with which I am most familiar, we have for centuries operated under the general objective of developing devices to more effectively destroy the enemy or his tools for making war. The competitive system to achieve this general goal does not have the rapid feedback characteristic of the other competitive systems because it requires a war in order to provide the checking process. However, until recently competition has been a very effective management system for achieving ever increasing effectiveness in our tools for warfare. Very little coordination and planning between nations has been necessary, and in fact within each nation also very little coordination between its different services has been used. We are now faced again with too much success. We have now developed, or soon will, the ability for any organization to achieve the means of killing all the people on earth. Again, through success of the competitive system we have overproduced and have developed strong pressures for more centralized planning and regulation.

To me, the crux of the problem of setting objectives for the management process is how to keep them broad enough and just impossible enough that people can generate their own methods of working toward these objectives and be judged by the impersonal process of competition. As each general goal tends to be reached, we have a choice between finding a better broader goal, or of slowing down progress by more central planning and curtailment of competition. I hope that the worlk will learn to generate enough more broad human objectives to allow each manager to set and follow his individual objectives and be judged by competition with his associates, rather than by some supreme centralized planner. I am not prepared to offer solutions in this area so let us assume we have an objective and proceed to our plans.

THE ESTABLISHMENT OF A PLAN

If a man knows where he is, and knows where he would like to be, then it would seem that a plan for getting from one place to the other would almost of necessity be obvious. Perhaps part of the present emphasis on the importance of planning comes from either having so many available routes open to us, or from the fact that sometimes our objectives are not clear and we are unable to specifically localize our present position. But in any case, from the manager's and bugetear's standpoint, a planned course of action is essential if we are going to martial the forces necessary to start moving.

Anyone who has managed research and development has generally experienced the violent reactions of research people to establishing detailed, specific plans for their work. I believe that this may very well be due to the fact that training in the scientific approach is a training in a method of procedure. Education of a man to do research makes the planning

of his work so much a matter of second nature that he cannot understand why people are always asking him "foolish" questions about what he is going to do next. All scientific work proceeds according to a plan which is highly stylized; and if a man's work is not carried out according to this plan, he is judged by his compatriots to be incompetent.

In order to understand the research man's reaction, let us outline a work plan which can be used for any research program. First, we must find out where we are by studying the literature, contacting others in the field, and finding out where information is inadequate and where long standing questions are unresolved. Second, we must search for some new hypotheses as to how things work, or how questions might be better answered. Third, we must design experiments of a critical nature to test the hypotheses which have been generated. Fourth, we must build equipment and carry out the experiments. Fifth, we will find that about once in ten times the experiment will be successful and the results can be published, recognized, and form the foundation upon which further work can proceed. Nine times out of ten the experiments will simply leat to new questions, new hypotheses, and a repetitive process of experimentation. I believe that it is primarily this low probability of success which makes the research man react so violently to the adoption of institutionalized management controls, ~~such as~~ PERT, etc. Once he has committed himself to a course of action on paper, in words which very few people understand, he finds it extremely difficult to change his course of action as his results dictate. If what he was doing was not understood because of its advanced nature in the first place, then the reasons he feels constrained to change his method of approach will be equally misunderstood. The only impression one can expect to generate from the normal budgetary planning of research and development is that the ideas proposed generally do not work, and we will need to eliminate nine-tenths of our research effort in order to make the whole organization profitable. This would be a reasonable course of action <u>if</u> we could solve the problem of picking the man with the correct degree of omnipotence to be able to eliminate the nine-tenths of the work which is unprofitable without also throwing out the one-tenth which represents progress.

I believe that external or organizational planning for research should concern itself with planning for the support and tools needed to encourage and assist good men. But we must immediately face the problem of how to choose these men. Judgement with regard to good research men is not an impossible management problem. Such men can be distinguished by their knowledge of the state of the art and knowledge of where the specific problems lie in their particular field. They have a high degree of enthusiasm for their work; they have more ideas than they have time to try; and they generally give the impression of having fun in the accomplishment of their job.

We often hear the philosophy that research cannot be planned. I feel that this is a gross mis-statement. All types of activity should be planned if objectives are to be achieved; and, as we have suggested, research in particular is highly stylized in its planning. However, if

it is good research of a truly creative nature, it should be sufficiently near to the boundaries of knowledge that very few people other than the research man involved will be able to understand or utilize the detailed plans which he will prepare. If he is forced to make such detailed breakdowns on paper in place of in his head, he can well be forced into spending most of his productive manhours trying to justify, with mathematical rigor, things which are likely to start out as informed, intuitive guesses.

If a management organization can't understnad or have access to research plans, then it will, of course, ask how can it be sure of achieving an end result on a time schedule which will allow the rest of its operations to proceed effectively and congruently? I am afraid that this is generally not possible. Plans and operations for the rest of the organization should be based on the known results of research rather than on the hope for a breakthrough. If an organization feels that it must have breakthroughs, then it should proceed on the basis of competitive programs with the expectations that approximately only one in ten of such programs will be successful in achieving the purpose intended. This will not mean that nine-tenths of their money is wasted, because the competitive situation will promote progress in all groups, but not necessarily toward the specific planned goal. The desire to complete a program ahead of their competitors will narrow the objectives of the competing groups and eliminate wandering. On the other hand, the group which wanders in spite of the competitive pressures may have a sufficienty good idea that it may repay the organization's expenditures on research and development for the next fifty years.

INDIVIDUAL MOTIVATIONS

Man is a planning and purposeful organism. Before he will operate effectively in any organization, he must have an individual motivation for the actions which he performs. The invention of money was the single most powerful tool in simplifying the manager's problem with regard to inspiring individual motivation. The needs of individual people can vary over a wide range. They include such things as food, housing, entertainment, power, etc. As long as these can all be expressed in terms of money, the manager's problem in handling individual motivation is simplified to controlling the single variable of salary. Large scale organized activity probably would not be possible without the simplication in the generation of motivation which is provided by the instrument of money. However, one of the peculiar problems in the management of research and development is what many of the motivations of research people seem to bear very little relationship to the money involved. The research man tends to be more interested in the importance of the job than he is in the salary involved provided the salary is sufficient to provide those of his needs which are common with other people, such as food and shelter. Money cannot buy for a man the recognition of the importance of his scientific work which he needs in order to feel secure as a person. Infact, it may work in the reverse direction. The desire to create, which is inherent in the true development man, can be implemented through the acquisition of money, but not if this money is achieved at the price of relinquishing his freedom of choice in the selection of what is to be created. Like creative men in other fields, the research or development man is likely to consider the expression of his personality through his work to be more important than financial returns from this work.

In order to motivate the research man, the manager must be sure that the objectives of the organization are worthwile, that the individual worker can see a relationship between the things he wants to do and the things which the organization would like to accomplish as a whole, and that the organizational attitudes are such that he can feel a strong sense of accomplishment when the goals which he sets as an individual are accomplished for the organization.

EVALUATION OF THE PRODUCT

For any organization or individual to feel successful there must be some mechanism for measuring the degree in which the goals which they have established have been fulfilled. In an organization which is profit-oriented, such an evaluation is straightforward, reigrous, and simple. If the figures are in the black, all associated with the organization are happy. If they are in the red, or tending roward the red, then something must be done to rectify the situation. Government organizations, military organizations, educational institutions, and research and development activities, whenever they are adequately removed from the profit making pressures, have a more difficult time in establishing a proper evaluation of the effectiveness of their processes and results. For all such organizations I believe the evaluation must be on the basis of competition similar to that involved in making a profit. The fact, however, that results cannot easily be expressed in terms of a single variable, such as money, tends to make the evaluation process much more difficult. Governments are judged by history, and military organizations by wars. These are very harsh and final judgments and do not provide a very adequate, self-rectifying mechanism.

I believe that one of the most useful things we can do to promote the improvement of research and development management processes would be to encourage mechanisms for evaluation competition between research groups. Instead of trying to eliminate duplication in the development of particular systems, we should concentrate on trying to establish generalized goals and techniques for judging the most satisfactory solution. Until publications become too voluminous to read, publication in technical journals performed part of this function for research. In the particular area of creative design, where I feel my special interest lies, I believe we should develop criteria for design, and evaluation procedures for design-critics very similar to those which have been developed in other artistic fields, such as music, painting, sculpture, writing, etc. Such criteria are admittedly inaccurate, subjective and judgmental in character, but they do provide a kind of public recognition of achievement for skills which sometimes require a negation of monetary reward for their proper expression. Evaluation of technical accomplisyments is a function which needs seriously to be performed, and I believe it is one which our society is now lacking.

To summarize, I believe that management for research and development is similar to other types of management is that it requires the establishment of an objective, the working out of a plan for accomplishment, the stimulation of individual motivation, and an evaluation of progress on the product in order to provide corrective mechanisms to insure continued improvement. It is particularly complicated by the fact that research

people, in general, have individual motivations which cannot be adequately covered by the common denominator of money. Much more individual attention is therefore required on the part of the manager to take care of these differences in individual motivations.

Life would be easy if the management of research were as straightforward as I recently heard it expressed by a man concerned primarily with the management of funds. His process was to lay out a planned schedule for the accomplishment of research objectives. At the end of a period of time, he compared how the work was progressing relative to the established schedule. On the basis of this evaluation, those projects which were falling behind schedule were provided with increased amounts of funds taken from a constant budget at the expense of those projects which were proceeding ahead of schedule. If this highly plausible budgeteer's philosophy of management is applied generally throughout R&D organizations, I am sure that it is easy to see that all of our efforts will eventually be confined to impossible projects. I hope that this is not the case; but sometimes, when I look over some of our military programs, I become concerned that such a management technique may be at work undetected.

THE ART OF SIMPLE AND RELIABLE DESIGN

William B. McLean
U.S. Naval Ordnance Test Station
China Lake, California

INTRODUCTION

The U.S. Navy is faced with the problem of putting ever more complicated equipment into operation by seamen who are generally available for only short tours of duty. This combination of complexity and minimum training often results in errors or malfunctions. It is therefore reasonable to expect that unless something is done, the loud cries for greater simplicity and higher reliability will continue to come from the Fleet users of our equipment.

What can we do in considering new designs to insure that the Fleet will have equipment it can use – equipment that will work?

I believe that designing simple equipment is an art, which like any other art requires an artist who understands his materials and who has the freedom, time, and encouragement to express his creative talents. We need such an artistic approach to achieve simple designs. Yet, as the size of our organizations increases, and the number of people waiting impatiently for each new design also grows, the opportunity for any designer to be creative disappears. Perhaps it is merely the pressures caused by the increasing size of government organization which account for the continued complexity of equipment, despite the universal desire for simplicity.

Dr. McLean obtained his BS, MS, and PhD degrees in physics from the California Institute of Technology. He was employed in 1941 by the National Bureau of Standards. He transferred to the Naval Ordnance Test Station, China Lake, California in 1945. Dr. McLean became technical director of NOTS in 1954. Special Government awards include $25,000 for the development of the SIDEWINDER air-to-air missile (1956), and the President's Award for Distinguished Federal Civilian Service (1958).

CHARACTERISTICS OF A SIMPLE DESIGN

In attempting to analyze such pressures, let us first consider what constitutes a simple design. By determining the nature of the thing we want, we may better be able to approach the problem of how to get it. The salient quality of a simple system is that it contain few parts and work every time it is tried. By virtue of its simplicity, it lends itself to ease manufacture and hence is producible in large numbers. The parts are designed so that they can be easily assembled, but not in the wrong positions or the wrong order. It does not have close tolerances unless these are easily maintainable in the manufacturing process.

Since it has few parts and can be rapidly assembled by unskilled people, it is of low cost. It requires a minimum number of people, with minimum training and skill, to operate it, and it is easy to maintain and requires a minimum of checkout equipment.

The final product is so simple and logical that it is difficult to imagine why so much time and effort were required for its development. The clue here is that, paradoxically, a simple design is anything but simple in its creation. It requires the utmost in creativity. In this sense it much resembles the work of a musician, or an artist, or a sculptor. The end product is completely integrated and functional. Its creation is essentially a work of art.

THE APPROACH TO SIMPLE DESIGN

Although there are no absolute rules for guidance, designing for simplicity – as in other forms of art – is most effectively accomplished when the responsibility for the complete system is carried by one man. If we are to have a truly integrated design, a single man must understand what he is trying to create, must be responsible

for the choices among the infinitude of alternatives available, and must weave the various elements of the design into the integrated system.

The concept of a single responsible designer for systems as complicated as those of our modern weapons has not been employed frequently in our current military designs. We tend much more to design by committee, and are likely to get results quite comparable to what one would expect if a painting were executed by a committee of artists. They might achieve a recognizable result, but it would lack the kind of integration in concept and execution that can be provided by the single artist. If we want to achieve simple, integrated design, we should employ the concept of appointing a single master designer for each system, who would execute his responsibilities in a manner similar to that of the architect of a building.

A second general principle in designing for simplicity is that the designer's freedom of expression and freedom of choice – as with the artist – should not be unduly hampered. Scientists and engineers are likely to be most creative when their supervision is such that they feel substantial freedom in their work – in selecting their problems and goals, in deciding on the approach to achievement, and in interpreting their data.

In this respect it is a fact of life that a simple, functional design is seldom produced in conformance to prior specifications. Simple design requires that the designer understand what is needed in such minute detail that specifications are superfluous. In fact, definite specifications reduce the opportunity for creative design by channeling the approach along preconceived pathways, thus causing the designer to overlook the really effective solution. For example, the broad objective of the man in combat is to influence human behavior. If asked about his needs he will undoubtedly ignore his broad function – if he is aware of it – and respond in terms of his immediate method of carrying it out by asking for a better gun. The more the creative designer can see an objective separately from the conventional methods of its accomplishment, the greater will be his opportunity for achieving an original and, hopefully, more simple solution.

A third principle of simple design is that the designer's ideas should be as free of organizational review as possible before they are executed. I have been impressed by the difficulties inherent in getting acceptance, or agreement, on the desirability of new ideas when first proposed. New concepts, in general, require modifications of our descriptive language in order to make them understood. The more novel the idea, the fewer will be the people with the background to understand it, and the more difficult is the transferring of information about it without the question-and-answer process. Our present management technique for the approval of funds, which involves review of written proposals with many checkpoints in series, is almost certain to weed out those novel proposals that might constitute major advancements. The proper time for review is after the design has been reduced to workable and understandable hardware. This review should then be very critical, before committing the large investments needed for production.

Thus far we have considered the designer as an artist and have dwelt mostly therefore on his freedoms and prerogatives. We might now turn our attention to what we expect of him. What are his qualifications, and how do we expect him to use them? What is the mechanism for achieving simple, low-cost design? Will he be conscientious enough to exercise his freedom properly and effectively?

QUALIFICATIONS OF THE DESIGNER

It is a dictum in the weapon-development business that the simpler the hardware, the more clever the developer has to be. To function at this level of attainment the designer not only must be intelligent but also must have a love for mechanisms that replace hand labor. In this sense one might say he should be lazy. He must have an intimate knowledge of all the tools of his trade. He must understand the need for particular skills that he does not possess and must be able to work with the people who have these skills in order to show them how to apply their talents to achieve the final results he has in mind. He must have the sensitivity required to live and feel the operational background for his product. In sum, he is an artist who must be selected on a basis of his professional skill and his demonstrated ability to produce outstanding designs.

HOW THE DESIGNEP PROCEEDS

The First Problem

Let us choose a designer for a weapon system and examine some of the activities he must

pursue in order to achieve a satisfactory final product. The designer will usually be given money provided by one man on the basis of a set of written specifications furnished by a second party. Seldom are either of these providers the ultimate consumer, who will be the final judge of the value of the product. In the case of commerical products, the ultimate consumer is the customer in the market place; for military products the ultimate consumer is the man in combat.

If our designer is to be truly successful, he must have a more direct contact with this consumer than can ever be provided by a set of written specifications. His first task is therefore to get out in the field and get clearly in mind the functions that the consumer would like to perform. Obviously a broad statement of problem will leave the designer much more freedom in creating novel solutions than will the problem as narrowed down by the terms of written specifications. The designer who does not take the trouble to try to broaden his specifications by understanding the basic problem will seldom deliver an outstanding product. Specifications for the improvement of vacuum tubes will not produce a maser or a transistor, but a wide basic understanding of the problems of amplification may. Similarly, it took a great broadening of the understanding of sea power to shift from the improvement of large guns and armor to the creation of the aircraft carrier. Such enlargement of concept is not easy, and our designers need all the help they can get through fundamental discussions of function with the users of their output.

Limits and Tradeoffs

The next task of the designer is to gain a thorough understanding of the factors which set the limits on the problem he must solve. Sometimes these are natural physical limits, such as the limits on detection of submarines set by the low permeability of water to all known types of radiation other than sound. Since no new types of radiation are reasonably foreseeable, this kind of limit is quite definite. Under other conditions the limits on the design are set only by the present state of the art, such as the operating-temperature limits of turbines, which will clearly change as new construction principles or easily foreseen new combinations of materials are developed.

Often the designer finds that he is faced not with a single limit but with a variety of possible tradeoffs under an overall limit, where the improvement of one desirable characteristic leads to a decreased ability to fulfill another desirable characteristic. In this sense, as we increase the range of rockets, bounded by the physical limits of the propellant energy, we are faced with an increase in the weight of the total system, which is an undesirable system characteristic from a logistic standpoint. In fact, as long as the military rocket is to operate within the atmosphere, we find that increased range can be purchased only at the expense of roughly a third-power increase in weight (i.e., doubling the range increases the weight by a factor of eight), provided that all configurations considered have been made optimum with respect to other limits (i.e., length/diameter ratio for spinner rockets, or length/stiffness ratio for finned rockets and missiles). The conscientious designer should therefore view with great skepticism any unsupported desires for increased range. In adjusting his tradeoffs, which is one of his most important responsibilities, he should study the relationships between the various parameters as functions of one another so that he can visualize how they will all vary in any change in his design.

Nonmathematical Factors

In addition to the mathematical relationships between different requirements, the designer should also understand clearly the relative importance of parameters that cannot be expressed mathematically. For instance, in the case of the Polaris submarine, the problem of contamination of the interior environment of the submarine by leakage from tanks of liquid propellants completely outweighed the fact that packaged liquid propellants have higher specific impulse, greater resistance to shock and vibration in large motors, and greater ability to operate over wide temperature ranges. Inherent limitations of the large solid-propellant motors, such as a need for uniform temperature control and a need for protection from vibration, were tolerable in the environment of the submarine. In this case we had to tolerate many limitations in order to obtain one outstanding safety advantage. The designer's choices, however, might be different if his rocket were to be transported outdoors and were to be exposed to wide variation in temperature and extreme conditions of prolonged vibration.

If we are designing military equipment to operate in an environment where the ability of a single unit to produce a kill is one in a thousand, or one in ten thousand (which is characteristic of a hand-held gun, then we should certainly expect to concentrate our attention on improving the accuracy or effectiveness of our weapons, rather than on the problem of simply shooting more of them. However, if we have achieved a weapon where the effectiveness is between 25 and 50 percent, as has recently been the case with the introduction of guided missiles, then our maximum improvement in single-weapon effectiveness can lie only between two and four. Such an improvement is easily offset by the use of larger numbers of weapons. Our designer in this situation needs to shift his attention from achieving greater effectiveness to achieving the same effectiveness at a much lower cost, with the resultant ability to use his weapon in greater numbers.

Similarly, the desire of the Navy to maintain supremacy in the ability to operate on the surface of the sea may completely outweigh all of the technical reasons for operating above or below the surface. This is a consideration that must guide our designer, or his solution - although it may be technically elegant - will not be useful to the consumer.

Misleading Specifications and Their Clarification

In cases where the designer does work from stated specifications, they can quite often be very misleading. During the Korean War an urgent requirement was received for an anti-tank warhead capable of penetrating 11 inches of armor. Since we knew that it would be impossible to fire perpendicular to the armor under all circumstances, we took a nominal value of 60 degrees for the obliquity of penetration and designed a shaped-charge warhead capable of punching a hole through 18 inches of armor. This weapon was delivered to the operating services in great haste. Some of us became curious as to the motive power employed by Russian tanks that would enable them to run around over rough terrain carrying armor 11 inches thick. Upon investigation, we found that the actual armor of the tanks had a thickness of somewhere between three and four inches, and that the specification given us had resulted from the correction for obliquity having been made twice before, while the specification was coming through channels. It is this type of well-meant distortion that makes it essential for the designer to question his specifications and to go back to primary sources in order to develop a real understanding of his problem and the basis for the need, if he is to create a successful product.

Choice of Design

Let us now assume that the designer has investigated his specifications, understands the problem, knows the relative importance of various design parameters, and has a good feel for the relationships between various tradeoffs. He now needs to outline as many ways of accomplishing the design as he can imagine. He needs to discover who else is working along similar lines, and, if possible, he should visit his competitors in order to find out what problems are bothering them in the types of solutions they are prosecuting. The designer needs to invent solutions to their troublesome problems if this appears possible, or try a completely new approach that will obviate these problems. He needs to check each of his new approaches against functional requirements and see how they compare with possible tradeoffs. He needs to look into the availability of components required to do the job and to see if those which are available will completely satisfy his needs, or at least will be adequate. If he judges them to be inadequate, he should not hesitate to design a new component to do the job more effectively. He should avoid being trapped into trying

to assemble off-the-shelf components; this technique can cut development costs, but it generally results in a much more complicated weapon and hence leads to increased production cost.

It is at this stage of development that the importance of having one man in charge becomes clearly apparent. The designer needs to run through a number of possible solutions and should check tradeoffs against the users' needs and the relative importance of the requirements. The number of possible solutions is usually quite large, and the relative tradeoffs are complicated and difficult to evaluate. The number of factors to be considered is generally too large to allow effective communication of all the possibilities by words or drawings. At this point the designer needs a working mental picture of how the components and the systems will operate and what changes will result as he puts different pieces into his design. Quite often, at this stage of development a completely different approach, which will be more effective from all aspects, may suddenly suggest itself. If the designer is fortunate, this will occur before he has committed himself too firmly to schedules, drawings, or specifications. Major changes are made most easily during the thinking and feasibility-checking stage. When the designer takes the next step and reduces his ideas to drawings, hardware, and time schedules, his ability to start from a completely different approach tends to become limited.

THE DESIGNER AND HIS PERSONNEL

We can assume that the designer has now reached the point where he has something that he believes is unique and that he hopes will meet the needs of the ultimate user in an outstanding manner. The kind of devoted, knowledgeable, integrated thinking needed for creating a simple design should yield a system that will perform properly under any reasonable set of circumstances. The designer is by this time very anxious and impatient to reduce his design to workable hardware so that he can check his concepts.

He needs now to collect about him a group of people who will provide the skills necessary to create the system, and he also needs the manpower and techniques required to construct the various components of the complete system. His vision of the complete system must be expressed by means of sketches and rough drawings that can be used by the engineers and technical people as a basis for detailed design and construction of the separate parts, so that they will fit into an integrated whole. Each of the supporting people must understand the complete design and must be able to communicate freely with the designer to be sure that the parts fit properly into the entire system.

The designer must now find men capable of assuming responsibility for each part of the system. Each of these men must feel that he has the freedom to conduct his program as he believes best. Any restriction of this freedom automatically releases him from the responsibility of making the final gadget work. It is here that the designer must walk the high wire of maintaining maximum freedom for his workers while at the same time maintaining a rigid discipline regarding the need for simplicity. An iron will is needed to direct a concerted and devoted effort to do everything the simplest way possible, and in a manner that will make the complete system work.

To do this best, he needs one organization, located in one place – and the smaller the organization, the better. Dr. Kershner, of the Applied Physics Laboratory, Johns Hopkins University, has pointed out that for every project there is an optimum size of organization (1). He postulates that if we plot the time necessary to accomplish a job against the number of people employed on the job, the curve will at some point have a value representing the minimum time required for accomplishment. Determination of the number of people representing the minimum value for different kinds of projects is the manager's responsibility. His job is particularly complicated by the fact that, at any point on the curve, all of the people involved in the project believe that the organization is too small.

In fact, as the working force passes the minimum number required and the rate of progress slows down, the perceived need for more people and more liaison increases rapidly. More engineers on the project can invent more avenues of approach and more techniques to try. The maintenance of coordination between all of these different possibilities becomes a function which again requires more people and more paper work. Competition for the available jobs becomes keen. Communications begin to fall off. The understanding of what is to be

accomplished becomes more remote. The need for definite specifications becomes greater. And, finally, the ability of each engineer to participate in setting up the goals toward which he is working, and his contribution to the total design, becomes less, with a resulting loss of interest. Tension within such an overstaffed organization grows, mistakes become more common, the trying of new things which might lead to significant shortcuts becomes entirely too risky, and the designer eventually loses control of the organization.

On the other hand, the closeness of a small organization stimulates continuous and rapid feedback between all the stages of the design process. Such feedback, provided by direct and rapid communication, is essential if we are to achieve integrated and functional designs. A small, effective organization can probably produce designs that are simpler and more reliable by factors of from 10 to 100 over the kind of equipment that results from the straight-line process of starting with the military requirement, building up a big organization, and wading through countless, detailed specifications.

DESIGN-BREADBOARD CYCLE

We normally think of simplicity not only in terms of reliability but also in terms of cost. However, it should be remembered that low cost may come only in production and not in the research and development areas. The reason for this lies not only in the extent of prior reasoning and planning that goes into the basic design, but also in the vast amount of building, testing, analyzing, and redesigning that goes into the development of workable components and a workable system. We can call this the design-breadboard cycle, and it is this cycling and recycling of the primitive components and system that leads us at last to a satisfactory prototype. Regarding this, Dr. Harold Brown, Director of Defense Research and Engineering, has said (2) "It is not feasible to push major weapon systems into production, bypassing the prototype stage as this is where 'bugs' are worked out. It may be possible with some items such as small arms which have lower production costs. But, even here, a small increase in production costs could offset any saving of skipping the prototype stage."

Since in designing for simplicity we are striving from something new, we should expect that many tests of the early components will fail; and that modification and improvement will be needed in order to make operable parts that will fit together so that the entire system will work. In this phase of the development the cycling time from drawings to construction, to test, and to redrawings should be as short as possible. Any interference with this process can completely upset the program. The designer should be intimately concerned with all phases of this recycling process in order that he can see and understand the deficiencies in his design and exercise his ability to correct them. He should make frequent visits to check on all of the components to see if they are progressing in the way he had visualized, and to make sure they will not distort the final product. He also must perform the function of rejuggling the compromises as some parts of the system become easier and other parts become more difficult to design effectively.

If we deny the designer the freedom to carry his product to completion, he will probably end up with the same kind of product that an artist might have if he let another artist fill in his rough sketches. Some of our more disastrously expensive programs have resulted from moving too rapidly through this testing and redesigning stage, with the hope that all the problems could be worked out on the production line.

It is sometimes argued that our designers will never stop improving their products if we give them all the time they want. I don't think this criticism will apply to the more creative, who are the ones we should choose to achieve simple designs. They usually have enough ideas available that they are more likely to drop a design too soon than to belabor it too long.

When the components are finally assembled into a working and tested model of the complete system, we reach the first point at which the services of the master designer, or architect, might be dispensed with and his design turned over to others for production. Even though such a shift becomes possible at this point, however, it is usually not desirable. As long as new problems arise, most designers would like to continue contact throughout production, although their interest can be expected to decline as the problems disappear.

THE HAZARDS OF SIMPLICITY

As every experienced designer has found out, designing for simplicity has a number of

hazards. In the first place, as we have already mentioned, it will probably cost more during the development period than would a straightforward assembly of existing components into a more complicated system.

Secondly, the development time is less predictable, because the development may depend on a new component, which may fail, or there may be serious mistakes in the basic conception which delay every other phase of development until they are corrected. There may be a long period required for working the normal bugs out of the system because of the interrelation of components in an integrated design. –

Thirdly, the more successful a designer is in achieving simplicity, the less equipment there will be available to impress the casual observer. People hold in great awe anyone who can understand the multitude of components and precision equipment that goes into one of our modern missile systems. The rewards for this type of design in terms of prestige and appreciation in our society are tremendous. Americans seem to enjoy complicated designs; a complicated car will sell better than a simple one that is functional in design. It is only the man with considerable personal experience in design who can really evaluate the inherent difficulties of a simple design, such as a safety pin. Since the designer of a simple mechanism usually achieves an article that is obvious immediately upon presentation, he will have difficulty explaining why he went up so many blind alleys before he was able to see the proper solution. In fact, he is quite likely to be criticized because he took so long and spent so much money in coming up with something that is patently very simple.

Perhaps we could alleviate some of these hazards of the trade by forming a design critic's association for mutual protection, except that the supply of "art" critics who have been trained to the point that they are capable of judging creative design is limited. We need to find a technique by which more unrecognized creative designers can test their skill and develop their talents before being put in charge of a major program which might involve the danger of complete and disastrous failure, both to themselves and their associates. We need also the skill of the professional critic trained to recognize that a design may be poor even though it works.

SUMMARY

I have endeavored here to show that reliability depends essentially upon simplicity, and that simple design is best approached by considering the designer first and foremost as an artist, giving him the same prerogatives we would grant an artist in the more classical fields. To attain simplicity and low ultimate cost in the design of our weapon systems, we need to satisfy the following specific criteria:

1. We need a master designer who must have complete responsibility for conceiving and bringing into operational condition all components of the complete system.

2. The designer must not be burdened with overspecification and over-review of his program, at least until his design has been committed to understandable hardware.

3. The designer must have the freedom to check and evaluate the specifications and the background for the specifications he is using in the creation of his product.

4. The designer must have the organization, tools, and facilities he needs to allow him to create, test, and recreate in a rapid feedback cycle under his own close supervision.

5. The designer, as he completes a workable design, needs the support of a management organization that has the ability to recognize and evaluate both his failures and his successes. By avoiding the former and exploiting the latter through production, management can make the product both available and useful to the ultimate consumer.

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1. Kershner, R.B., "The Size of Research and Engineering Teams," Proc. Eleventh National Conference on Administration of Research, Penn State Univ. Press, pp. 77-83, Sept. 1957.

2. Brown, H., "On Defense R & D," Product Engineering 32(37):112 (Sept. 18, 1961).

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The Role of Government Laboratories in the R&D Process

This section contains the following speeches in chronological order:

"Position of Government Laboratories in Military Research and Development Programs," presentation to a joint meeting of the China Lake, Palmdale, and Lancaster Rotary Clubs, Mojave, California, 13 March 1958

McLean states his belief that "one of the most important errors of our present administration [the Eisenhower administration] ... is the decision to concentrate all of our military research and development in industrial laboratories" and argues that the idea part of the process must be maintained in government laboratories.

"Operation of Navy Laboratories in a Society Dominated by Technological Progress," presentation to the 10th Annual Meeting of the Senior Scientists' Council of Navy Laboratories, Naval Ordnance Laboratory, Corona, California, 7-9 March 1960

McLean gives a brief overview of how the U.S., Britain, and Germany historically met the need to develop new military equipment. Stressing the importance of communication among military and civilian participants in the weapon-development process, he discusses why he believes Navy laboratories to be better than those of the other services.

"Why I Work at NOTS," draft paper, audience and intended publication unknown, January 1961

In this draft McLean lists the forces, both positive and negative, that in their summation make him want to continue working at NOTS. The positive forces generally come from the strengths of NOTS itself, while the negative forces he describes are the "annoyances and tribulations" emanating from higher bureaucratic levels and affecting all government laboratories. He concludes that China Lake can and should take advantage of the "freedom we have because of the lack of continuity and the organizational confusion in Washington, if we have the courage and vision necessary to exercise it."

"The Mission of NOTS," presentation to the Kern, Inyo, and San Bernardino County Supervisors and members of the Death Valley Forty Niners, China Lake, California, 20 January 1961

"We are very fortunate to have so many of the elements of the design process in one location and in one organization," McLean says. Mentioning the difficulty some China Lakers had in explaining that NOTS was more than just a "test station," he suggests that the Spanish term "experiancias," translated as meaning both "experiences" and "experiments" might be "the type of name which we have been looking for."

"Military Research Must Be a Government Function," presentation at the Third Symposium, Fifteenth National Conference on the Administration of Research, San Juan, Puerto Rico, 10-13 October 1961

McLean describes three systems that support U.S. military R&D objectives: (1) direct Civil Service operation, (2) contracts administered by universities or other nonprofit organizations, and (3) negotiable cost-plus-fixed-fee contracts with major defense firms. "I believe that the government must do its own research within its Civil Service Laboratories so that it will have the ideas, the competence, and the capabilities to say in what directions the work should proceed," he says, assigning the in-house laboratories up to 50% of the development role in his ideal system, with industry's role to be primarily in the production area.

"Our Changing Mission," presentation to the annual meeting of the Missile and Astronautics Division, American Ordnance Association, China Lake, California, 8 April 1965

To illustrate his contention that China Lake has two types of missions—a continuous broad mission as a major Navy laboratory and a changing mission describing "what we are doing now and hope to do in the future"—McLean traces significant changes in NOTS' work over the years, discussing how these changes have affected the Station's mission.

"Utilization of Federal Laboratories," presentation at hearings conducted by the Subcommittee on Science, Research and Development of the Committee on Science and Astronautics, House of Representatives, Washington, D.C., 27 March 1968

From his perspective as Technical Director of the Naval Undersea Warfare Center and former Technical Director of NOTS, McLean discusses the R&D effort in Federal laboratories, along with some of the strengths and problems of the in-house laboratory system. He briefly describes management of the ASROC weapon system to illustrate excellent in-house management of a large program involving a wide range of governmental and industrial activities. He then addresses specific questions dealing with laboratory management, funding, and workload balance.

"Bill McLean on Laboratory Management," ***News and Views,*** **Naval Weapons Center, May 1968**

News and Views, a management newsletter that was widely distributed within NWC in the late 1960s and early 1970s, reprints quotations from McLean's 27 March testimony before the House Subcommittee on Science, Research and Development (see previous speech). Ideas presented in brief are on the laboratory mission, on system design, on funding for independent research, and on the necessary rate of organizational change.

U. S. NAVAL ORDNANCE TEST STATION
China Lake, California

Presentation to Joint Meeting of Rotary Clubs (China Lake, Palmdale, Lancaster) at Mojave, California, 13 March 1958

POSITION OF GOVERNMENT LABORATORIES in MILITARY RESEARCH AND DEVELOPMENT PROGRAMS

by

WM. B. McLEAN
Technical Director

Gentlemen:

I would like to discuss with you tonight my opinions as to the place of government laboratories in our research and development program for military equipment. Since my opinions are somewhat at variance with our present national policy, I will try to explain how we have arrived at our present position, and then why it should be changed. If my comments are sufficiently obvious to occasion no comments or questions, I will be disappointed.

The last two world wars have been won largely through the productive capacity of the United States. In these wars the sheer weight of more ammunition, bombs, and equipment turned the tide of war as soon as our productive capacity was organized to produce. With this background it is not surprising that we have placed a great deal of emphasis on our ability to produce in our military program. We have appointed production-minded people as secretaries of defense; we have dispersed our productive capacity; and we have built numerous guided missile plants and facilities. But more importantly, we have worried about the difficult problem of transition from research and development to production. For any product this is a difficult transition and requires that the development people maintain interest in the new product while the production people are encountering the numerous problems which will arise while the product experiences its first contact with producibility. It is obvious that this transition can be facilitated if the two groups (production and development) are part of the same organization. Our concern with production has therefore led us to what I consider one of the more important errors of our present administration which is the decision to concentrate <u>all</u> of our military research and development in industrial laboratories with a consequent lack of interest in our government-sponsored military laboratories. If production of military equipment were our main problem, we would be proceeding correctly, but I am concerned that production of military equipment is not the means by which we will maintain our position in the world. We probably already have as many bombs as will ever be needed and more than adequate means to deliver them.

The Russians have shown a remarkable ability to challenge us to types of contests which we have not previously considered under the rules for war. They have set up contests for limited objectives, such as the occupation of Berlin, Korea, Suez, etc. They have challenged us to a display of technical achievements through such firsts as the jet transport and the satellites. I think the stage is now set for a challenge to our productive capacity by supplying the "have-not" nations with whatever they need to improve their local economy. If successful, this threat will be very embarrassing. While we are producing large numbers of Atlas, Thor, Triton, and Jupiter missiles, Russia will be delivering durable goods to Africa, India and perhaps South America and establishing her currency as the international medium of exchange. Our foreign aid program will be only a poor substitute in this contest. What we really need is a truly free exchange of goods. We seriously need to decide what we would like in return for our large existing and potential surplus of consumer goods. It is unreasonable to expect that we can continuously give them away and accept nothing in return.

I have digressed somewhat, but an economic contest will need free shipping which may be difficult in the face of a large submarine fleet, and certainly can't be done via the moon in spite of what some of the newspaper stories would have us believe.

It seems to me that the power of nuclear weapons has made military production relatively unimportant, has made all-out war of the nuclear types very unreasonable and perhaps even unprofitable, and has put an extreme emphasis on the need for fresh, new ideas for conducting military operations of a very limited type. This is the area in which we need government laboratories.

I would assert that the industrial laboratories are handicapped by a natural desire to improve on what exists, by military specifications that are unimaginative, and by the fact that only one customer can exist for a military product. Also important is the fact that military science is a tremendously broad field. So broad, in fact, that only the largest industrial organizations can even begin to support the breadth of skills needed and still make profits.

I would like to close with a quotation about the need for a government laboratory to do aeronautical research and development which applies as much today to military missiles as it did when it was written in 1915 about airplanes.

> "It appears that the interest of colleges is more one of curiosity than that of considering the problem as a true engineering one, requiring development of engineering research and, therefore, as not yet of sufficient importance to engage their serious attention," the NACA commented in its first Annual Report. "Manufacturers are principally interested in the development of types which will meet government requirements or popular demand, but which will not involve too radical or sudden changes from their assumed standard types."

Particularly this last problem still exists and the problem of change of tooling still works to prevent radical change in product.

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OPERATION OF NAVY LABORATORIES

IN A SOCIETY DOMINATED BY TECHNOLOGICAL PROGRESS

by

Wm. B. McLean, Technical Director
U.S. Naval Ordnance Test Station
China Lake, California

Presentation for the 10th Annual Meeting of Senior Scientists' Council of Navy Laboratorites held at U.S. Naval Ordnance Laboratory, Corona, California, 7, 8, and 9 March 1960

Gentlemen:

I am very happy to have the opportunity to introduce the discussion on the Navy Scientists' Participation in Formulating Concepts, Requirements, and Designs for Weapon Systems.

I would like to begin by broadening the discussion to include condideration of techniques for obtaining the right military equipment in a society where technological advancement is extremely rapid. At the present time, new ideas and new equipment are being generated so rapidly that they hold a dominate role in national policy. Whereas our ability to produce in past conflicts has been the determining factor in our military operations, we are now confronted with the fact that a single technical improvement can completely overpower any degree of productivity.

In the past, several techniques for the obtainment of new military equipment have been tried. Historically in the United States, we have followed the policy of stating military requirements which result from the needs of military operations; we then ask the technical groups to design equipment to meet these objectives with a specified solution. This system has the advantage of being businesslike and straightforward, but the disadvantage of discouraging feedback of those technical possibilities which would produce painful changes in the military requirements.

A second system has been used in Great Britain. This was set up following World War II and Consists of having a civilian Ministry of Supply which is charged with doing all the research and development on new military equipment. The British Ministry of Supply studies the needs of their Army, Navy, and Air Force, and then provides them with the new technical equipment which the Ministry believes will be most effective in carrying out the needs and requirements of the various armed services. This method of operation is characterized by the statement made by the British Ministry of Supply that it is their purpose to supple the equipment which the armed services really need, rather than the equipment which they think they need. The strength of this system is that it supplied a good mechanism for balanced choices between various technical possibilities. It has the weakness that it tends to inhibit the acceptance of new technical equipment by the military services. Further, the requirements of the military services may not be adequately understood by the people developing new equipment.

A third system was the pre-war German system which turned out to be suprisingly effective. Germany consisted of a large number of cities in which one industrial organization tended to play a dominate role in community life. Under these circumstances, it was quite natural that the industrial organization tended to assume many of the functions of government. In particular, the industrial leaders had the feeling that they had the responsibility for the national defense of the country. In order to discharge this responsibility, the various industrial organizations met jointly to plan the various elements required to accomplish the national defense program and to delineate the responsibilities of each

industry in this program. This is a very efficient system in that duplication is reduced to the vanishing point and each industry has a specific job to perform in order to produce the most effective national defense. It is a system which, without doubt, has produced military equipment on the forefront of the technology available at the time it was employed. The weakness of the system is that it gives industrial organizations a position in the national political scene which is probably not acceptable either in the United States or Great Britain. It also provides a direct industrial incentive to the involvement of the nation in war-like operations at such time as the equipment has reached a satisfactory stage of development. This system is now being replaced in West Germany by a Department of Defense patterned after the one existing in the United States. The old German system is probably acceptable now only in the USSR where complete integration of government, military operations, research and development, and production facilities is taken for granted.

The high degree of diffusion of authority, which was built into the United States Constitution in order to make it difficult for any group to seize political control of the country, makes it extremely difficult for us to achieve rapid technical change in our military equipment at the present time. We have won two major world wars purely on the ability of our industry to out-produce the rest of the world in military equipment. In World War II, in addition to starting production on equipment which had been developed prior to the outbreak of hostilities, it was also necessary to start the crash development of new types of equipment. It was realized that our military designs were not up to the maximum allowable by technology existing at that time. It was considered urgent to get research results incorporated in new equipment and crash development programs were established at such laboratories as Los Alamos, MIT, the National Bureau of Standards, CalTech, etc. In these laboratories, we made use of the background of technological training which had been built up in the universities and was available for application on military equipment. Specifications for new equipment were at a minimum. Everyone was aware of the actual problems which needed to be solved, and there was a quick interchange between technological solutions and the military needs. The military organization was involved in a struggle with an adversary armed with superior equipment and very little hesitancy existed in making use of new devices as they were developed. Again, because of the mass of goods required, industry played a dominate role in the successful accomplishment of this military operation. It is significant to note, also, that only a relatively few of the industrial laboratories were equipped with the type of research operation necessary to design new equipment without benefit of specifications.

With the development of the atomic bomb at the end of World War II, we have a demonstration of a technological improvement which cannot be off-set by any consideration of quantity of production. Since the war, in the guided missile, the intercontinental ballistic missile, and the nuclear powered submarine, we have similar improvement in weapons technology which cannot be off-set by simple increases in numbers of slightly inferior weapons. We have, therefore, reached the stage at which technological advance is sufficiently rapid that it

can drastically re-shape the structure of military operations. Under these conditions, it is not obvious that technical developments should follow the statement of military requirements. It becomes increasingly plausible that the military requirement should be shaped as a result of technical achievements in new equipment. Indeed, it is becoming painfully obvious that, in spite of tremendous resistance to this idea, this process is actually occuring. This reversibility of procedure means that a continuous interchange of information must occur between technical personnel and military operational personnel.

I have now been engaged in technical work on military equipment for a total of 20 years. In this period, I have witnessed both very effective and very poor exchange of information between technical scientific personnel and the operating military personnel. At times, the operation proceeds very smoothly, and, at other times with other personnel, it comes to a complete and grinding halt.. The proper technique for achieving the communication necessary in order to develop highly advanced technical military equipment seems to me to be one of the most pressing problems facing our nation today. It will not be an easy problem to solve because, while there are good technical people in uniform, the forces that shape military operations and military personnel are not those which normally attract the type of personality interested in a better understanding of the secrets of nature. Many of the values which make for good military operations, such as tight organization, strict carrying out of command, careful planning, and respect for authority, are exactly those things which are very detrimental to the operation of a creative, wide-awake laboratory. I believe that all of our experience would indicate that the ability of laboratories to come up with creative, imaginative, new weapons ideas is inversely proportional to the domination of these laboratories by unsympathetic forces, military or otherwise. On the other hand, acceptance of new equipment, the support of this equipment by the military organization, and the effective use of this equipment is probably proportional to the involvement of military personnel in the development of the equipment.

In order to get the best types of military equipment, we are faced with the challenging problem of making two groups work closely together who have different motives, different values, different objectives, and different methods of expressing themselves. The solution will not be trivial. In this type of operation, I believe the Navy has demonstrated that it is possible for scientists to work in a military organization and, at the same time, maintain the freedom of action, choice of goals, and technical integrity which are necessary in order to maintain a competent technical staff. This condition has, however, been attained in only a minority of our existing military laboratory establishments. Examples of laboratories in which the technical people have the necessary freedom to operate are the laboratories of the Bureau of Naval Weapons, such as NOTS, NOL-Corona, and NOL-White Oak; the laboratories of the Bureau of Ships, such as NEL and NRDL; and the Applied Physics Laboratories at Johns Hopkins and Seattle. I am sure that all of these laboratories will agree that these conditions can be maintained only by a vigorous and determined effort. We are continuously surrounded by administrative procedures which tend to inhibit creative work. Our operations are a minority in the government organization. We are considered

both alien and upsetting and very difficult to control by administrative rules. Most government regulations are intended to apply across-the-board. The application of such rules to a research and development laboratory can cause the degeneration of this laboratory into a condition of complete stagnation. I believe it our duty to continuously object to the boradside application of such non-applicable regulations. In our laboratories, the technical programs must be planned, coordinated, and executed by scientific personnel with a maximum degree of freedom. We should expect the military operational involvement to be on the basis of discussions of military needs, advice on the execution of programs, and assistance in getting the equipment accepted for military operations. If, at any time, the military operational involvement becomes greater than this, the laboratory finds itself developing a split personality. The most imaginative technical people become discouraged first, and the technical degeneration can become so complete that the laboratory loses its ability to understand even its own weaknesses.

The record of the Army in the operation of its technical laboratories is not as good as that of the Navy. In most of the Army arsenals, parallel positions exist at all levels which are occupied by military and civilian personnel with substantially equal degress of authority. In this type of operation, the civilian person achieves his authority by reason of continuity in the job, whereas, the military man holds his authority by regulation. This type of operation is ideally designed for conflict and is not the type of organization in which a self-respecting scientist can accomplish effective technical work. Military personnel assigned to this type of duty are equally frustrated. The Army has had a few laboratories, such as the Jet Propulsion Laboratory, Von Braun's group at Redstone, and the Diamond Ordnance Fuze Laboratory of the National Bureau of Standards, in which the organization was primarily a technical operation. These laboratories have been highly effective. Tow of them have recently been shifted to the National Aeronautics and Space Administration thereby drastically diminishing the Army's competence in the development of technical equipment.

The Air Force has practically no civilian technical competence. It has further stated its intentions to be the training of a military technical corps who can be expected to be more responsive to administrative demands than the disturbingly, unresponsive civilian scientists. The once creative laboratory at Wright Field has become largely a contract administration group. The operations at Eglin Field are primarily of a testing and evaluation nature. The Air Force is forced by this lack of technical competence to contract not only its development work, but also its technical thinking with regard to what new equipment is needed. In the Rand Corporation, the Air Force has an effective non-profit, thinking and planning group who are limited only by their separation from contact with hardware and by the fact that the Air Force largely ignores their recommendations. Air Force planning is therefore more a result of political, rather than technical thinking.

A serious handicap we face as scientists working for the Navy is that all government scientists are considered by the administration to be of equal

competence. Whereas, in fact in the Air force, the civilian technical man is almost non-existent. The Army operates a major fraction of its laboratories in such a way as to attract only mediocre personnel. Many of the Navy laboratories are subject to some of the same handicaps. It is, therefore, understandable that all government scientists get tarred with the same brush, and the general comment that government scientists are largely incompetent is not too unreasonable from the standpoint of the over-all administrators in Washington. It is understandable then that administrators in Washington feel the need to purchase technical competence through industrial contracts. Industry does have good technical people and is effective in exercising them so that they produce good equipment for industrial purposes. Therefore, the question is often asked, "Why isn't this a good method of operation?", and, "Why can't we close our government laboratories and solve, at one blow, all the problems which revolve around the difficulties of military-civilian operations?" I personally would be happy to see this occur if the stakes involved were less than our national survival. I become increasingly convinced that it is impossible to secure the military equipment necessary to safeguard the country by the technique of writting purchase specifications in contracts, and then asking technical organizations to carryout and build the equipment to match these specifications. The difficulty in this system lies in the rapid rate of advance of technology to the point where the feedback between the technical people doing the actual work, and the military operational and purchasing people who are writing the specifications cannot be accomplished. Even some of the most general specifications, when implemented in accordance with physical laws, tend to design a complete system. The competent scientists in industry are thereby prevented from exercising the ingenuity which distinguished them as competent scientists. If one asks an engineer working on a government contract for the reasons behind his choice of particular design parameters, the most common answer is that it was what they were asked to build.

If properly applied, I believe that 10% of the national product should be adequate to supply us with a military defense. A casual glance at the newspapers will convince any technical man that this defense is not being accomplished. When one reads of vast sums being expended to catch nose-cones in nets, plans for NIKE-ZEUS to knock down incoming intercontinental ballistic missiles, designs for even more expensive anti-missile missiles, propostions for bombs in orbit, for military stations on the moon, or for world-wide ocean surveillance systems, one becomes convinced that the technical judgment of the United States in military matters has reached such a low ebb that the country need no longer be considered an effective military threat. In comments of the Soviets on the overplanning of our space program, one might even detect some suppressed laughter. I believe that the laboratories represented here have a large responsibility with regards to our national military program. We could review the military budgets, completely separated from the political arguments, and reach substantial technical agreement on which programs should be prosecuted and which programs should be eliminated. We have recently attempted this in the ASW program and our efforts, I believe, have met with considerable success. I am convinced that any program which would result from such a technical evaluation would in no sense resemble that which is now being prosecuted. As technical laboratories of the United States Government

and as one of the few groups able to make judgments separately from the pressures of profit, we need to make such an evaluation and use the competence, which we have, jointly to produce a better understanding of the problems now effecting the safety of the nation. We represent the small residue of people interested in technical problems who are almost ignored in an atmosphere which is primarily dedicated to the solution of administrative problems. How can we break through the administrative haze?

In conclusion, I would like to summarize by stating that it is my firm belief, as the result of 20 years of experience in this type of work, that the system of contracting which the government has been employing for the last ten years has had adequate time to demonstrate its weaknesses. The system of buying technical thinking by industrial contract is not succeeding and cannot ever be expected to succeed as long as the specifications and the contracting officer dominates and controls the technical thoughts. The planning of the military defense of the country is a government function established by the Constitution. The various alternatives provided by modern technology are so closely associated with the decisions which must be made on national policy that policy and technical thinking cannot be separated. It is, therefore, no longer possible to do the national thinking for the future as a government function and expect to buy technological advice by industrial contract since this separates them in both time and organizational location. The two need a much closer relation. The Navy laboratories represent one of the few remaining places today where responsible technological thinking is available within the government. We, as the directors of these laboratories, need to organize a crusade to see that this thinking will be applied to the multitude of serious decisions which now face the national policymakers. If this crusade is not successful, I would predict that we will be faced with the problem of continuously yielding to the pressures of the more integrated planning of our opponents.

8 Mar 1960

THE MISSION OF NOTS, by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California. Presented to the Kern, Inyo and San Bernardino County Supervisors and Members of the Death Valley Forty Niners, Commissioned Officers' Mess, 20 January 1961

I would like to speak to you about the philosophy of operation of the Naval Ordnance Test Station.

The Station was started in 1943 as part of the complex operated by the California Institute of Technology which was concerned during the war with the production of military rockets. At the end of the war this complex of operations broke up and part of it became the Aerojet-General Corporation, part continued under the management and direction of CalTech as the Jet Propulsion Laboratory, and the remainder was taken over by the Navy and operated under Civil Service regulations as the Naval Ordnance Test Station. Our mission was stated to be the conduct of research, development, and test of military equipment, such as rockets, aircraft fire control, and underwater ordnance.

As the war ended, it was foreseen that each of the Services would have to set up organizations to carry on the kinds of work which had been conducted during the war by the Office of Scientific Research and Development. The organization and laboratory constructed at NOTS was the result of the desire of the Navy's Bureau of Ordnance to continue the kind of scientific investigation into military equipment which had been so successfully carried out by various universities and technical organizations during the war. In the beginning, long discussions occurred relative to the value of building a laboratory in the city where it would be close to production facilities, universities, and other types of scientific investigation, versus the alternatives of building it here in the desert where the scientific work and scientists would be close to the opportunity to carry out experimental verification of their ideas and the equipment which they produced. Many of us had spent most of the period of the war designing equipment, taking it to test sites, waiting for the weather to become favorable, and then trying to repair the equipment in the field away from our laboratory facilities. When the decision was finally made to locate the laboratory at the test site, it was from this group of scientists (who had been continually frustrated during the war by the difficulty of testing military equipment) that many of the early recruits to the NOTS organization were found.

At that time the ability to test new equipment and to revise it quickly in accordance with the results of the test, seemed to be the important part of our mission. More recently we have come to regret the fact that we are called a "test Station" because most organizations throughout the country have been separated by functions--those doing research do not necessarily do development, and those doing development very seldom also do testing. In this way the cycle is open-ended rather than regenerative and we find ourselves continually faced with the problem of explaining why a "Test Station" should be heavily concerned with everything from basic research through the time when the equipment we have conceived is being used in fleet operation. Because of this confusion, we have been anxious for many years to change the name from "Test" to a term which would have broader

and more all-inclusive connotations. These attempts at name change have for various reasons been unsuccessful.

A few weeks ago, I received a Christmas card from the Secretary of the Navy in Argentina which translated the name of the Station int Spanish. The card was addressed "Al senor Director Tecnico de la Estacion Naval de Experiencias de China Lake." On checking this in my Spanish dictionary, I found that "Experiancias" can be translated by either "experiences" or "experiments." This is the type of name which we have been looking for. In our operations we combine the military experience of the Naval officers with the scientific experiments of our technical people in such a way as to produce new and better equipment for use by the Navy. It therefore would seem that the real meaning of the word "test" has somehow been lost in our organizational definitions, and it has picked up such connotations as "only test" and "just testing." However, if one thinks about it for awhile, it is possible to see that testing is really the backbone of all scientific work. It starts in the research laboratory where new theory is being tried out and checked. It continues through the building of the experimental equipment. It determines whether a manufacturer is producing useable equipment and continues with the equipment out into field operations. Our facilities here are organized to make the maximum use of experiments and experience to design equipment which will not fail when it is put to the test on the battlefield.

Our first-hand experience with the testing of military equipment convinces us that those things which are unduly complicated are worse than useless because they require manpower which could otherwise be more usefully employed, and the possibility that such things will operate when required is negligibly small. One of the crusades, therefore, of this organization is to eliminate all unnecessary functions and requirements. We are very fortunate to have so many of the elements of the design process in one location and in one organization. Our organizational closeness stimulates continuous and rapid feedback between all of the stages of the design process. Such feedback, with its requirements for direct and rapid communication, I believe is essential if we are to achieve truly integrated and functional designs for our military equipment. We believe that the kind of organization we have here can produce designs which are simpler and more reliable by factors of from ten to one hundred times over the kind of equipment which results from the straight-line process of starting with the military requirement and proceeding through countless more detailed specifications.

I would recommend strongly that more organizations throughout the country be set up along the lines of the Naval Ordnance Test Station and be equipped with the capability of working in all areas of the problem at once--starting with basic research and ending with assistance to the fleet with regards to training problems. Such organizations will not be able to do more than a fraction of the total job, but they will be able to provide guidelines and a framework. Such a framework will make it possible to fit in the other organizations that have become specialists in particular areas. The specialists, given a framework and a master plan, can then work together to produce an integrated, complete system. Since industrial success is achieved largely through specialization, many laboratories or research centers, such as NOTS, are needed if the government is to make the most effective use of the country's industrial potential.

MILITARY RESEARCH <u>MUST</u> BE A GOVERNMENT FUNCTION

by

WM. B. McLEAN, Technical Director
U.S. Naval Ordnance Test Station
China Lake, California

resented at the Third Symposium, Fifteenth National Conference on the dministration of Research held at the Hotel San Juan Intercontinental, an Juan, Puerto Rico, 10-13 October 1961. Host: College of Agriculture nd Mechanic Arts, University of Puerto Rico.

Ladies and Gentlemen:

I would like to begin my expression of biases on the relative roles of various types of laboratories by first defining a set of goals for these laboratories. Second, I would like to specialize on the methods of operation of laboratories performing military research and development; and third, I would like to talk about the pros and cons relating to the various methods of operation which have been employed in doing military research.

I believe our laboratories divide rather naturally into organizations with three different sets of goals. The objectives of these laboratories might be defined as follows:

(1) Those laboratories working with the objective of furthering projects which have been assigned as definite government responsibilities.
(2) Those laboratories working with the objective of improving industrial products.
(3) Those laboratories who have the objective of furthering the general state of knowledge.

Laboratories working on projects which are government responsibilities are subject to close public scrutiny and various forms of political pressure. Success is measured in terms of new hardware developments with reliability dominant over cost.

Those working on industrial products are subject to pressure to produce results which will eventually be applicable to products for production. Their efficiency is measured by the degree to which production resulting from research is profitable for the company supporting the research. Cost is a crucial consideration.

Laboratories working toward the acquisition of new knowledge are subjected to the fewest pressures and can therefore be considered to have the greatest degree of research freedom. If, however, they are to continue to receive support either from private grants or from educational institutions, they are subject to the pressure to publish their conclusions in a form which will be understandable to others and will allow their results to interact with other fields in order to promote further progress. One might say that success of the university research workers is measured by the degree of understandability which they and the university can achieve in the communication of ideas. Sometimes these ideas are so complicated that fairly intensive educational programs at the graduate level must be established before a comprehending audience can be created.

During the last twenty years, I have worked for the Bureau of Standards and for the Navy Department and have been concerned primarily with the laboratories working toward the objective of furthering projects which are definite government responsibilities. It is in this area that the major competitive situation between laboratories have arisen. For this reason and because of my background, I would like to stay in this area for the remainder of my discussion.

Over the course of the years, the Government has tried many different methods of operation in order to accomplish the research, development, and production of those types of equipment for which it has a unique responsibility. The first such technique was to establish government owned and operated laboratories in which the personnel were hired as direct government employees. These jobs were classified in the Civil Service system in order to insure uniform standards throughout the country and to protect employees from the capriciousness of their bosses and varying political pressures. In a manner characteristic of all large organizations, the complexity of Civil Service regulations increased, while the flexibility, and the ability to change in response to varying circumstances, decreased. When the war started in 1941, a more flexible system for accomplishing government research and development was obviously needed in a hurry. The Office of Scientific Research and Development was set up and the university organizations throughout the country were called in as managers of government-type operations. This led to the university contract to perform a government function under direct government control, but without the administrative restraints and other handicaps imposed by bureaucratic regulations. At the end of the war, many of the universities wanted to go back to their prime job of teaching. They felt that government support of any appreciable fraction of their total operation might lead to government control of the whole operation. Also, the salaries paid on government projects tended of necessity to be somewhat higher than university salaries and, in the eyes of the university, their work of a somewhat lower caliber than that being conducted by the university professors. These differences have produced organizational strains in the university structure.

After the war, many committees, such as the Hoover Committee, were appoint-d to study the problem of obtaining advanced military technology for the overnment, such as that which had been achieved through the Office of cientific Research and Development. These committees noted the bureaucratic nflexibility and lack of progressiveness of the Civil Service organization. n particular, they observed that an outstandingly inflexible type of operation as achieved when the constraints imposed by the military departments were dded to those of the Civil Service organization. These committees collected any statements from the better scientists indicating that this type of rigid ontrol was not likely to produce the freedom necessary for rapid advancement n the scientific areas. It was also noted that many industries had very mpetent laboratories working on the improvement of industrial products. It as proposed that the government use these industrial laboratories to work on vernment projects. It was hoped that this would be a flexible arrangement n that it would allow the use of people from the industrial organization ly when they were needed on a government project and would allow those eople to return to industrial problems whenever the government work was not rgent. This system, which has much to recommend it on philosophical grounds, believe, has been found impossible to implement except in the case of very all organizations. The objectives and goals of people working on government projects are so different from those of people working on industrial ojects that the organizational strains between the two groups become intolable. Each major industrial organization has found that in order to handle vernment projects it must set up a separate "government industrial" divion which has as little contact as possible with the rest of the industrial eration. The government industrial divisions, so organized, have therefore

become another type of government laboratory. These laboratories stand or fall primarily on their ability to get approval for projects from government contracting agencies. Needless to say, this is the least stable type of government laboratory and the one least equipped to do the long range basic of applied research which will lead to new types of military equipment.

The basic flaw in the industrial-type contract lies in the government administrator. Operational and administrative experience alone, without knowledge of the technical problems, does not provide sufficient wisdom and insight to allow the establishment of a reasonable contract which will define the new products that the Government wishes to procure. Without such a contract to specify the activity of the industrial laboratory, and without an experienced technical man monitoring the contract in order to modify it as new scientific facts and test results become available, the Government and therefore the Public of the United States is wholly at the mercy of the good will and good intentions of our large industrial organizations. If we are satisfied with this goodwill, then I am sure that the corporations will need the freedom to discharge their responsibility for the development of new military equipment which can only be achieved by also assigning to them the basic responsibility of providing for the national defense. The establishment of mercenary armies ready for hire, for example, from General Motors and General Electric seems to be a step more drastic than the people of the country are as yet ready to take. I expect, however, that these armies would be more realistically equipped with less expensive equipment than the ones we have in the field today.

As long as the government retains the responsibility for providing the national defense it must also have available a competent government contracting authority. This need has led to the creation of special not-for-profit corporations such as MITRE, IDA, RAND, Lincoln Laboratories, STL, Aerospace, etc. The desire to purchase technical judgment has been particularly crucial in the case of the Air Force which has a minimum of in-house technical competence and the maximum problem with regard to the amount of money which must be placed in industrial contracts. These operations have had varied degrees of success, as just outlined by General McCormack. The General Accounting Office report of the investigation of the ballistic missile program appeals to me as a very good summary of the reasons why such organizations have troubles. Instead of going into these problems in detail I will simply recommend this report for your study. (Reference (I))

SUMMARY OF METHODS OF OPERATION

To summarize the methods of operation, I believe that in the past 25 years the Government has found three workable systems for providing support to the laboratories engaged in furthering specialized government objectives such as military research and development. These three are: (a) support through a direct Civil Service operation, (b) support through a management contract administered by a university or other non-profit organization, and (c) support of the government industrial division of major companies through a negotiable cost-plus-fixed-fee contract.

Civil Service Operation

Taking the pros and cons of each of these organizations in order, one can ive on the pro side of the Civil Service operation the values of greater tability, greater identification with the general objectives of the total overnment organization, better understanding and better communication (both ɔ and down in the organization) of needs, requirements, and methods of fulillment of requirements. Also, greater acceptance by the public of a basic ntegrity and a freedom from the suspicion of working for personal profit.

On the con side, we have entirely too many regulations of an out-dated naracter. The Civil Service scientist is part of one of the largest organzations in the world and is continually troubled by policies and regulations nich were stated in general terms for the total organization and have no pplicability in his particular circumstances. The pressures for centraliation of functions which occur in all large organizations are particularly eleterious in the case of Civil Service operations. The military interretation of regulations often compounds their effects. We have special ashington groups concerned with such specific functions as personnel, ransportation, auditing, construction standards, rental and utility charges, nd even recently a survey board got enmeshed in how people engaged in overnment projects should worship.

University Contract Operation

The government laboratory operated through university contract has greater reedom with regard to establishing pay scales for its employees, even though nese scales must be maintained comparable with those of the university staff. niversities also have greater freedom with regard to establishing functionalype support under local control.

On the con side, they have more limited access to basic military operation. data, and their communications both ways within the government organizations e more restricted than those of the civil service operated laboratory. It more difficult for them to establish need-to-know criteria and to gain ccess to information on other related contracts.

Industrial Contract Operation

To me, the industrial contract is one of the poorest ways of operating laboratory for the government. The only real advantage is that whatever laries are needed to hire people can be paid, and almost unlimited conruction of new facilities can be accomplished. On the other hand, the ntract laboratory's access to government classified information is usually ewed with suspicion. It is very difficult for them to establish the need-know, particularly in regard to contracts being carried out at similar vernment industrial organizations, or even with respect to Civil Service d university government organizations. The cost-plus-fixed-fee contract ts a positive incentive on making every development cost the maximum amount ich the company can negotiate, since profits increase with cost. This leads the hiring of large numbers of engineers, the division of each project

into sufficient sub-units so that these engineers can be employed on sub-components, and the combining of these sub-components into some of the most complex systems the mind of man can create. The tendency toward complexity is aided by the desire of contracting agencies to write definitive specifications which are only by accident in accord with the technical realities of what might be achieved by simple designs. If an engineer in one of these organizations has some esthetic feelings which have not been completely killed by his association with engineering monstrosities, he may try to change some of the contractual specifications in such a way as to allow for a more elegant solution than the straightforward contractual one. He immediately runs into the suspicion that what he wants to do is for the company's gain and that any relaxation of government specifications may work to the detriment of the government. The suspicion that he is incompetent because he can't make things work the way he promised to in the first place is always present. Very few engineers with high motivations and good esthetic taste are able to stand up to this kind of questioning of their motives and integrity by someone who hasn't a ghost of an idea as to the purposes to be accomplished. They usually give up and produce what the contract asks for.

We now have enough such government industrial organizations scattered through the country that the least suspicion of the possibility of a new project will bring forth 70 to 80 unsolicited proposals based on the hope of getting the lead in bidding for a contract which is essential for survival of the organization. This method of operation insures that a large percentage of our most competent and creative engineering manpower is now going into the preparation of proposals which, on a statistical basis, cannot expect to have more than a 2-3 percent acceptance. Added to all these difficulties, these laboratories have company pressure to show a profit, and the uncertainty of their survival if they fail as engineering salesmen. It seems to me to be quite reasonable that the salaries for the people in this type of operation should be at least double those required to keep equally competent people working in the civil service-type of laboratory, or in the university or non-profit supported laboratory. Their frustrations must be at least doubly great.

CONCLUSION

In conclusion, I believe that the government must do its own research within its Civil Service Laboratories so that it will have the ideas, the competence, and the capability to say in what directions the work should proceed and what objectives it should achieve in those areas where the government has the sole responsibility, such as military research and development. This will insure that the government will have a source of competent technical people capable of exercising a broad view in the management of its contract operations. The very decision by the government that it must do its military research within its own organization will eliminate the most important obstacle to its accomplishment. I believe that none of the obstacles in the Civil Service operation are insurmountable, but the attack on these obstacles will not begin until the decision is made that the attack is necessary, and we cease looking for easier alternatives.

In the development area, the government needs to do a certain percentage of .ts work in order to develop the people who will be competent to evaluate the esults of other development projects and to see that they meet contractual bligations. The percentage of development work might be up to 50 precent of he total.

In production, it would seem that industry is best able to provide the lexibility in operations needed to achieve high production at low cost. When esearch and experimental development are finished and the government can pecify clearly what it wants and can write realistic performance or inspec- ion procedures, then the competitive spirit inherent in the production-type f operation can be effectively made to work to produce a superior product t a minimum cost. The production capability of American industry has un- uestionably won the last two world wars in spite of perhaps superior research nd development capability in Germany. If we consider Khrushchev's recent tatement that the next conflict will be one for economic superiority in the orld, then it is certain that American industry will again be called upon to emonstrate to the world that it has a creativity in industrial projects and productive capacity which cannot be equaled. Industrial design to capture ew world markets seems to me to be a challenge that should be very inspiring) industrial organizations. They should be quite content to leave the un- :ofitable and frustrating areas of research and development on equipment, iich is of interest only to a single purchaser such as the Department of efense, as a function to be performed by organizations established primarily or this purpose. American industry vitally needs to concentrate its research d development efforts toward more imaginative commercial products which will monstrate industrial leadership throughout the world.

Dr. King spoke Tuesday of Great Britain's steps toward entering a common rket in Europe. I hope that the United States will be able to compete fectively in such a market with the goal of a higher standard of living for l. Personally, I prefer this type of worldwide cooperation to the mmunistic world organization.

Dr. Minton spoke of the need for more scientists. I believe we are wasting large percentage of our most effective scientists in the preparation of pro- sals, serving on review committees, and in other administrative nonsense at has no relation to the job to be accomplished.

If we can free our scientists for technical work, by the decentralization administrative controls, we should have more than enough to advance the andard of living in all countries at a dizzy pace, as well as to take care the relatively simple military requirements.

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DEPARTMENT OF THE NAVY
U. S. NAVAL ORDNANCE TEST STATION
CHINA LAKE, CALIFORNIA 93557

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Presentation to American Ordnance Association, Annual Meeting, Missile and Astronautics Division, China Lake, California, 8 April 1965

"OUR CHANGING MISSION" - by Wm. B. McLean, Technical Director

Members of the American Ordnance Association:

An organization such as NOTS has two types of mission--a continuous broad mission which describes our goals and capabilities in general terms, and a changing one which describes what we are doing now and hope to do in the future. Our fixed mission is to provide better weapons for the fleet to help discharge its functions. Our capabilities cover a broad spectrum from research through development and assistance to industry in production, to test and assistance to the fleet in training and use. The Navy, however, operates in a changing world--its functions change and our specific working missions must be able to change fast enough to be ready to meet the new needs. I thought it might be useful tonight to review how our specific jobs have changed over the years, and discuss the branching process of research and exploratory development needed to keep our capabilities for new work changing faster than the needs.

The Station was started in 1943 by the California Institute of Technology as an area in which to test rockets, warheads, and fuzes, and to train pilots of fleet squadrons in their use. Even at that time this work represented only a small part of our working mission, the biggest expenditures of funds being involved in the design, the construction, and then the operation of a propellant plant to manufacture extruded solid propellants for rockets. At its highest rate of production, this plant produced 10,275, 2.75 rockets per month until industrial sources took over the load.

Probably our largest and least recognized area of work, because of the security, was initially concerned with atomic weapons. The final assembly of the first weapons, the manufacture of the explosive components for these weapons, and their testing to determine the weapon ballistic coefficients, were all accomplished at NOTS. To attest to our changing mission, one can recognize that none of these activities is now a significant part of our workload.

Our next change in area of work grew out of the facilities which we had available from rocket testing and fleet training and might be defined as the era of the development of range instrumentation for the purpose of understanding what was happening. This involved both the accurate location of the trajectories of ballistic missiles on the ground ranges, and an investigation of what happened when an aircraft fired rockets. Our goal in the aircraft rocket

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field was to determine those factors which contributed to the total rocket error and to investigate means for correcting these errors. We were surprised to find that wind tunnel tests of an aircraft did not accurately determine its angle of attack to better than a few degrees, and that this was a very important factor in the flight of rockets which must be determined for each individual aircraft in actual flight tests before accurate fire control predictions could be made, and of course the angle changed during the life of the aircraft.

In 1948, as our ground range personnel were testing the Applied Physics Laboratory's guided missiles and coming up with ways of making them better, it was decided that having NOTS in the field of development of guided missiles, and at the same time trying to test them, would complicate management functions. Therefore, our mission was amended to exclude the development of guided missiles. This exclusion coincided almost identically with the conclusion of the aircraft fire control people that the only sensible way to design an aircraft fire control and rocket system was to simplify the fire control sufficiently to allow it to be put in the rocket. For a time we developed such fire control systems without calling them missiles. This included the period when we defined them as fuzes which had the function of moving the rocket toward the target, and in fact designed them to be mounted on the front end of a standard rocket motor and warhead in order to occupy the normal position of a rocket fuze. The conflict between a specific exclusion of an area of work in our mission and the things we were capable of doing, and were actually doing, was finally resolved and the Station has taken its place strongly in the area of developing guided missiles to the point where we now have six different guided missiles in service in the fleet and four more well along in the development cycle so that they can be expected to be in service in a few years.

I believe the area of guided missile technology is now in good shape and we have enough basic information, guidance techniques, and other component capabilities to allow us to continue to turn out both air-launched and surface-launched missile systems which will effectively fulfill Navy needs for the next ten years. I expect that we can continue to design systems which will be both low in cost due to using the minimum number of components which will achieve a function, and reliable because of our belief that missile designs are not adequate if we can foresee any conceivable way in which the system will fail. I have some argument with the reliability programs which predict a certain percentage of reliability. If we know that certain components have a probability of failure before the design is completed, it would appear expedient to eliminate such components from the design. Our experience shows that there are sufficient unforeseeable ways for a design to fail to make it inexcusable to leave in any predictable mechanisms for failure. As our new missile systems become available, I think we will achieve the capability of being able to hit any target on the ground which we can see, any ship on the ocean whether we can see it or not, and any aircraft which flies within aerodynamic range of our missile installation, many of which will be passive and therefore difficult to locate. The radar countermeasures can be easily foreseen, however, we do not at the present time have any good ideas for the countering of optically guided systems because of the possibility of tracking with extremely narrow fields of view. It would seem that the predictable conclusion of our guided missile

activities will lead us to a point where the Navy may have a vital need for new vehicles and for new alternatives relative to its future course of action.

Our present job in the research and exploratory areas should be directed toward establishing laternate branches for progress which will maximize the possibilities of action relative to warfare or, more broadly, of human behavior in the future. It is hard at the present time to predict what our future specific working mission will be, but the facilities and capabilities which we now have available allow a wide range of possibilities to think about--such things as applying non-lethal weapons in the appropriate psychological environment is of possible interest. Our work on the study of porpoises for hydrodynamic reasons initially, and more recently for the purpose of comparative behavior, may lead in this direction. The modern molecular chemistry shows that all animal brains consist of the same kinds of molecules. A study of cross-species behavior would indicate that there are perhaps more similarities than differences in behavioral responses. We have felt for a considerable time that the non-lethal gases might serve as a good training aid relative to human behavior in much the same way that the radio-controlled electric dog collar assists in training animal responses. At the present time it is probably a very poor tactical weapon if used without psychological preparation as has been recently demonstrated in Vietnam.

A completely different area of new technical growth resulted from our research on chemical compounds and from our knowledge and physical facilities to compound new propellant compositions. This has resulted in a convenient mechanism for the generation of large quantities of silver iodide. One of our new projects is sponsored by the Bureau of Reclamation and concerns the increase of precipitation in the Kern Valley. I hope you have noticed that it has been very successful in the past few weeks.

Another technological branch for new growth was initiated by the work we have done on torpedoes and underwater launching for POLARIS. This has led us to the use of our missile technology and our very competent shops in the design of vehicles such as the one Dr. Cheatham mentioned this morning, MORAY, and an observational vehicle for range and oceanographic operations which is called DEEP JEEP. This vehicle has carried men to a depth of 1,100 feet and has been tested unmanned to a depth of 2,500 feet. We are making arrangements with Scripps for its use in a study of the La Jolla Canyon. NOL White Oak has recently shown that glass spheres appear to be the ideal structural material to take man to the bottom of the ocean. I believe we have the technology and facilities to exploit this type of design in the interest of extending the Navy's mission into exploring and using the volume of the ocean. This may be a course of action which will give the Navy a new capability with respect to both commercial and military applications.

One of the interesting comparisons discussed this morning by Dr. Cheatham related to the continued need for manned aircraft as well as missiles in air combat. In the underwater atmosphere, the need for manned weapons would seem to be even more necessary than in the air environment. In this environment, classification is even more difficult and the rate of progress of the combat situation much more suitable to a manned capability with respect to response

time and discrimination.

In conclusion, I believe it is the job of research groups in the Navy to keep a multitude of avenues open to allow the Navy's operational planner a freedom of choice in a very difficult future environment where we do not yet have a clear understanding of what we would like to accomplish through our limited military operations, nor an understanding of mechanisms to use for combat when our missile technology makes our loss rate of ships and aircraft unacceptably high.

We will now demonstrate the TIARA system which is another of the branches for new technology along which progress is being made toward service use.

UTILIZATION OF FEDERAL LABORATORIES

Hearings Conducted by
SUBCOMMITTEE ON SCIENCE, RESEARCH AND DEVELOPMENT
COMMITTEE ON SCIENCE AND ASTRONAUTICS
HOUSE OF REPRESENTATIVES

Presentation By

DR. WM. B. McLEAN, TECHNICAL DIRECTOR
NAVAL UNDERSEA WARFARE CENTER

MARCH 27, 1968

I appreciate this opportunity to talk with you about the research and development effort in Federal laboratories. Before answering your specific questions, I would like to make some general comments.

As recognized by this group in its present inquiry, the management of research has become a national problem of some magnitude. The researcher is no longer concerned only with purely technical problems, but also with the application of his technology to social, economic, and political problems on a national and an international scale. I am of the opinion that research is never a job that can be completed, but will continually expand as more positive results become available. It is, therefore, obvious that no single organization can ever attempt to cover all possible areas of research, even in a very superficial manner. I believe it should be our objective in research to make sure that our work is as near the frontiers of knowledge as is possible; that we are working in those areas where we have strong interests and the proper tools to carry out the research; and that we are continually searching for a better understanding of nature and are always on the lookout to find discrepancies in our known knowledge which will lead us to interesting new possibilities.

We know that federally financed research and development can be accomplished through several different means: the in-house laboratory, the Government-owned facility operated by a contractor, universities provided grants or contracts, contracts with non-profit organizations, and contracts with private corporations. All of these types of

management structure appear to work equally well. To me, the crux of the problem is not the type of organization but the process of setting management objectives for the organization so as to keep them broad enough and just impossible enough so that people can generate their own methods of working toward these common objectives and be judged by the impersonal process of competition. Management of the development of our weapons systems is a complex and complicated task requiring not only the skills to solve the purely technical problems, but also the highest order of management coordination. Let me illustrate from my past experience as Technical Director of the Naval Ordnance Test Station, a laboratory of approximately 5000 people engaged principally in the development of air-launched weapons - now the Naval Weapons Center.

The ASROC weapons system involved an extensive research and development effort whereby NOTS as lead laboratory for the Bureau of Naval Weapons undertook project responsibility for development of the entire weapons system, including propulsion, fire control, launcher, and development of the torpedo, and test and incorporation of the nuclear depth charge. This required interfaces with a wide range of governmental and industrial activities, including several Navy bureaus, the Atomic Energy Commission, and numerous prime and subcontractors for production of the system and its component parts. The laboratory's involvement with this program started with the definition of a Fleet need. It carried through concept development, feasibility demonstration, prototype development, contractor direction on production, and finally Fleet introduction.

NOTS was able to accomplish this program because of its broad mission, extensive experience in a variety of program areas, and diverse technical skills. It is my belief that a broad charter and work experience utilizing skills from many disciplines are essential keystones to undertaking large systems developments which must be supported by the effort of many agencies. In addition, some one must have the desire, determination, and skill to establish and maintain control of all the variables involved.

The concept of a single responsible designer for systems as complicated as those of our modern weapons has not been employed frequently in our current military designs. If we want to achieve simple, integrated design, we should employ the concept of appointing a single master designer for each system, who would execute his responsibilities in a manner similar to that of the master architect of a building. If we are to have a truly integrated design, a single man must understand what he is trying to create, must be responsible for the choices among the infinitude of alternatives available, and must weave the various elements of the design into the integrated system. Like an architect he must understand the tools of his trade. An outstanding example of such an architect is Admiral Levering Smith in the Polaris program.

To conclude my opening comments - In the planning of military equipment, with which I am most familiar, we have for centuries operated under the general objective of developing devices to destroy more effectively the enemy or his tools for making war. During recent years our national R&D effort has achieved for us the capability of near total destruction. I believe now, that our national goals have shifted a portion of our R&D

attention to "limited warfare", which in effect is the extension of police methods and weapons against international crime. The control of crime on a national level and waging conflicts such as the one in Vietnam would seem to have many aspects in common. It is highly probable, as your questions suggest, that we will see the use in international settings of the techniques and equipment developed for control of national crime and vice versa.

Gentlemen, I now will address myself to your specific questions.

SOME FACTS ON YOUR LABORATORY

PLEASE PROVIDE A BRIEF HISTORY OF YOUR LABORATORY, WHY IT WAS ESTABLISHED, WHAT ARE ITS PRESENT FUNCTIONS, AND WHAT YOU THINK IT SHOULD BE DOING 10 YEARS FROM NOW. ALSO WE WOULD APPRECIATE INFORMATION ABOUT YOUR PRESENT HUMAN, MATERIAL AND FINANCIAL RESOURCES. TO THE EXTENT THEY ARE NOW AVAILABLE, WE WOULD APPRECIATE SETS OF ANNUAL REPORTS, BROCHURES, ETC., THAT DESCRIBE YOUR LABORATORY.

The Naval Undersea Warfare Center is a relatively new organization, established on July 1, 1967. The functions and programs, however, that were brought together to make up this new organization were already well established within the Navy laboratory structure, and will provide the take-off point for new program developments.

This new organization was part of a general Navy plan to restructure in-house laboratory effort into "centers of excellence" for improved utilization of laboratory resources. The plan encompassed the development of a number of self-contained organizations, to include enlarged systems integration capabilities, with each center working toward the identification

and solution of specific and related military problems.

The Naval Undersea Warfare Center was created from elements of the former Naval Ordnance Test Station and Navy Electronics Laboratory. It is a primary research, development, test, and evaluation activity of the Naval Material Command, and is responsible to the Chief of Naval Material for the administration of assigned funds, conduct of operations, and the accomplishment of the mission. The mission of the Center is to support the Fleet by originating and analyzing new ideas in undersea warfare and ocean technology, by translating these into effective operating systems and by assisting in the introduction of resultant undersea warfare systems and technologies into production and service use.

The work of this Center covers a wide range of research and development in such fields as underwater optics, underwater acoustics, military oceanography, sonar technology, oceanometrics, fluid dynamics, lasers; and advanced computer techniques, and systems developments in submarine launched weapons, deep submersibles, homing torpedoes, deep sea salvage systems, deep-operating research vehicles, fire control systems, underwater sensors, and search and recovery systems. I have provided your committee with brochures and reports of our work. Some of the material describes the work of the new Center organization; some from the former Navy Electronics Laboratory and the Naval Ordnance Test Station describe our ocean research and sensor development, ASW developments and ocean engineering programs prior to the reorganization of last July which transferred these programs to the new Center.

NUWC is currently operating on the original sites of the two primary laboratories from which the Center was formed. The Center has major laboratories both in Pasadena and on the Point Loma waterfront at San Diego, California, with additional research facilities at Mission Beach, San Diego, California; Kaneohe Bay, Oahu, Hawaii; Cape Prince of Wales, Alaska; and Lake Pend Oreille, Idaho. The Center operates test ranges at Morris Dam, Long Beach, and San Clemente Island in California.

The Center is currently operating with a civilian ceiling of 1400, including 567 scientists and engineers. We have 350 assigned military personnel. The budget for this fiscal year is $51.1 million. Resources in technical facilities and equipment assigned or used by NUWC, are valued at approximately $100 million.

The functions of this laboratory are moving in the direction of designing equipments and techniques needed for the inspection, exploration, and control of the undersea environment. A broad mission in this area is required for the support of the Navy's undersea warfare effort. The programs on the detection and tracking of submarines are primarily classified and designed for control of the seas. They involve sonar systems, advanced data processing, weapons and fire control, as well as investigations of the structure of the oceans of the world on a regional basis. The Report of the Panel on Oceanography of the President's Science Advisory Committee (issued by the White House in June 1966) provides us with excellent guidelines for exploration and use of the sea during the next 10 years. National goals as expressed in this report are: prediction and control of the sea's phenomena for safety and economy of sea going activities, the full development of marine resources for man's use, and more strategic use of the

undersea environment to enhance national security.

The Naval Undersea Warfare Center work at this time includes effort in all of these areas. The Center is currently a strong element in implementing the recommendations of the President's Science Advisory Committee. For example, NUWC was designated by the Chief of Naval Material as the lead laboratory for the Deep Ocean Technology Program. The Interlaboratory Task Team working on this program is coordinating its effort with the national agencies and committees working in the fields of oceanography and engineering.

Other efforts now underway are in such areas as marine biology, oceanography, underwater photography, and the man-in-the-sea program. These provide NUWC with skills and capabilities for the pursuit of research and development tasks for other agencies outside the Department of Defense.

Let me discuss a little further the ten-year mission of the laboratory. The most difficult problem for the laboratory director is to understand and evaluate the multiple conflicting inputs which he receives, and from them choose a course of action for the employment of his limited resources to do research and exploratory work on which to base future programs. His guesses may be inaccurate but he must make them. My guess at the present is that the Navy will continue to execute its historical mission of exploration and control of new resources and of providing the tools for furtherance of the United States' international aims. The changes during the next ten years will reflect the facts that the new resources are on the sea floor and that the exertion of political pressure by the United States is limited by the existence of mutual atomic deterrence.

We at the Center therefore should be putting research and exploratory effort into:

1. New equipment to explore and operate on the sea floor.
2. Understanding how to define limited and definite objectives.
3. Creating a variety of the precise tools, equipment, and procedures needed to achieve objectives of limited scope.

It would appear that a limited war operating with clearly defined objectives involving persuasion rather than destruction will require procedures similar to those needed for the control of crime under the objectives created by national law.

A NATIONAL POLICY FOR LABORATORIES

BASED UPON YOUR EXPERIENCE, WHAT DO YOU THINK ABOUT THE DESIRABILITY AND FEASIBILITY OF A STRONG FEDERAL POLICY FOR FULL USE OF EXISTING GOVERNMENT LABORATORIES AS ONE ALTERNATIVE TO ESTABLISHING NEW LABORATORIES AS NEW AGENCIES AND PROGRAMS COME ALONG?

This question is related to the whole problem of organizational life cycle. A laboratory of the type I have been associated with takes at least five years to become productive and after perhaps twenty years has come to know its field so well that it is sure that nothing new is likely to arise; (i.e., change requires knowledge applied to new problems.) The continuing resource and essential product of government laboratories is the accumulated experience of its people. The organizational problem is to continue to generate changes which will allow this experience to be applied in new areas. Organizational changes are needed at a rate matched to the effective life cycle. For R&D labs, changes at rates less than five years will stop productivity and at

more than twenty years will promote atrophy. A federal policy which would ensure that the changes in laboratory management and mission are slower than five years and more rapid than twenty might be considered desirable for maximum return on the investment made in creating "experienced laboratory people." Present procedure of establishing new organizations as new needs arise is probably good if it can be coupled with a mechanism for transferring people and facilities from organizations whose effectiveness and missions are disappearing. The procedures for disestablishing laboratories should be improved. In the real world many organizational loyalties make the dissolution process extremely difficult. In the process of selecting between laboratories, as in any growth process, competition is very important. Therefore, if the government were to establish clearly defined, narrow and exclusive missions for its laboratory organizations, it would eliminate competition and would soon be faced with the complete coverage of all areas of technical endeavor by organizations convinced that nothing can be changed and all new projects are worthless.

Within the effective life cycle of a laboratory I believe the laboratory can develop its competence to the highest degree if it is exposed to a variety of problems. The legal limitations on accepting work from other agencies have presented no problems. The general belief that there is a definite relationship between manpower and performance does present problems. My own experience would indicate that people can perform at rates at least an order of magnitude (factor of 10) different depending on interest or lack of it in the work being undertaken. Interesting programs are easy to add to an already full workload. As Parkinson states in one of his

organizational laws, "Work expands to fill the time available for its accomplishment". I believe that only by overloading development groups can we be sure of maximum return. We should by all means encourage interagency use of laboratory facilities.

AGENCY GUIDANCE ON LABORATORY USE

WHAT POLICY STATEMENT, DIRECTIVES, ETC., HAVE YOU RECEIVED THAT GUIDE YOU IN DECISIONS WHETHER TO PLACE SOME OF THE WORK ASSIGNED TO YOU IN ANOTHER FEDERAL LABORATORY, OR TO AGREE TO PERFORM RESEARCH AND DEVELOPMENT FOR ANOTHER AGENCY?

The policies are generally permissive rather than directive. The procedures for placing work in other laboratories or accepting work from other agencies are well established and can be utilized on a mutual agreement basis. There is much merit in doing work for multiple agencies. There is no substitute for being known by one's peers and outside effort accomplishes this objective. Interlaboratory contacts also provide data for the comparison of Civil Service standards.

There are limiting factors that control the amount of outside workload that can be accepted. These limiting factors are the physical plant, the mix of scientific talent available, existing program commitments, and restrictions on the use of resources (overtime limitations, for example). Laboratories lack a fast reaction time when new facilities are required. As you know, to construct new facilities requires a minimum of five to six years from the time that the requirement is first known. There needs to be more flexibility in construction for research and development activities.

Because of the complicated array of factors affecting laboratory workload, it is difficult to assess the laboratory capability remotely. This assessment should be a prime function of the laboratory director assisted by his staff.

INDEPENDENT EXPLORATORY FUNDS

SINCE A PRIMARY RESPONSIBILITY OF A LABORATORY DIRECTOR IS TO SUSTAIN AND IMPROVE THE CAPABILITIES OF HIS MEN AND TO KEEP THEM IN THE FOREFRONT OF THEIR FIELDS, TO WHAT EXTENT CAN YOU USE FUNDS ASSIGNED TO YOUR LABORATORY FOR INDEPENDENT EXPLORATORY RESEARCH? WHAT LIMITS ARE PUT UPON YOU? WHAT ACCOUNTING DO YOU HAVE TO MAKE FOR THEIR USE? HOW WOULD YOU BALANCE THE NEED FOR FLEXIBLE AND QUICK RESPONSE TO NEW OPPORTUNITIES IN YOUR WORK AGAINST THE EQUALLY VALID NEED FOR CONTROL AND ACCOUNTABILITY IN THE SPENDING OF PUBLIC FUNDS?

TO WHAT EXTENT HAVE YOU HAD EXPERIENCE WITH DIFFERENT MECHANISMS FOR SUPPLYING INDEPENDENT RESEARCH FUNDS, SUCH AS SPECIFIC FUNDS FOR THIS PURPOSE FROM YOUR PARENT AGENCY, FUNDS OBTAINED FROM ANOTHER AGENCY, OR THE CHARGING OF SOME INDEPENDENT EXPLORATORY RESEARCH COSTS TO LABORATORY OVERHEAD, TO BE SHARED BY ALL USERS OF YOUR LABORATORY'S SERVICES? WHICH, FROM YOUR STANDPOINT, IS PREFERABLE, AND WHY?

The Laboratory Director has complete control of the line items in the budget allocated to independent research and independent exploratory development. I believe that one of his most important functions is to apply these resources in such a way as to investigate new ideas of the laboratory personnel. The ability to act quickly on new suggestions is very important in maintaining the morale of scientific people.

In selecting from ideas, which are always more numerous than the funds available, the director must have clearly in mind the needs of his parent organization and the state of technology. He should give highest priority to suggestions that will provide developments which the organization will need in the next five years and to experiments which attack critical questions on the forefronts of technology.

The independent programs are reviewed after the fact, and future allocation of new funds are made on the basis of judgments on the success of each laboratory's past programs.

The most unbiased judgment of a director's use of independent funds is the degree to which the laboratory secures development projects from the parent organization based on information and demonstrations made possible by independent work.

Of the various methods of supplying independent research funds, I would favor the one which assigns a certain percentage of the total budget of the laboratory for this purpose. The rewards for careful use of the funds to guide developments toward things which are needed by the sponsoring agencies will, in this case, be automatic. Cross agency use of the laboratories will be improved and will provide that each user pay part of the support needed to develop laboratory competence.

PERSONNEL CEILINGS

IN THE ADMINISTRATION OF YOUR LABORATORY, ARE CEILINGS SET FOR PERSONNEL? IF SO, HOW ARE THESE CEILINGS SET? HOW DO YOU BALANCE THEM AGAINST ALLOCATIONS OF FUNDS? HOW FEASIBLE IS IT TO OBTAIN A CHANGE IN PERSONNEL CEILING TO DO WORK FOR ANOTHER AGENCY? HOW LONG DOES IT TAKE?

Civilian personnel ceilings are set for the laboratory by the Director of Navy Laboratories who receives a total allocation of billets for Navy laboratory operations from the Office of Civilian Manpower Management. The Navy ceiling, of course, is derived from overall DOD and Executive Establishment limitations. Hirings are made based upon funds available to support a certain employment level, within the established ceiling. Increases to the ceiling depend upon a number of factors including need, total employment level within the Department of the Navy, and ceiling points available within the system for reallocation. Typically, the laboratory ceiling is not adjusted for performing particular projects, whether these are Navy sponsored or for another agency. Rather, the laboratory is expected to adjust its total resources, which should in the long run, represent the optimum size and skills mix to perform a broad spectrum of work to meet priority needs. I might repeat that there is value in a workload consistently higher than the laboratory can handle, since the pressure of taking on additional interesting work tends to force out low interest and low pay-off programs and promotes the early transfer of work to industry. However, with an accounting system where an efficient operation can be judged and rewarded, the need for manpower ceilings as a control could be removed and greater flexibility obtained.

BALANCE OF WORK

IN YOUR EXPERIENCE, WHAT IS THE BEST RATIO BETWEEN RESEARCH AND DEVELOPMENT SPONSORED BY YOUR PARENT AGENCY AND WORK FOR OTHERS? TO WHAT EXTENT DO YOU THINK THAT COMPETITION BETWEEN FEDERAL LABORATORIES FOR PROJECTS OF OTHER AGENCIES CONTRIBUTES TO THE ENERGY AND VITALITY OF THE COMPETING LABORATORIES?

No single ratio will apply to all activities. In the laboratories where I have worked, the ration was about 90% for the Navy and 10% for other activities. I think this is a reasonable split to provide outside contacts and exchange of information. In military laboratories it might be desirable to have as much as 5% of the effort supported by non-military agencies. We have performed work supported by other agencies or of direct benefit to them, such as warhead and missile tests for the AEC and Army, provision of Ocean Range Facilities for NASA and major industrial firms such as Lockheed, North American, General Atomics, and Westinghouse. Other effort includes undersea geologic maps used by the Geologic Survey, assistance to the Air Force and AEC in recovering "lost" objects, calibration work on instruments, assistance to Arctic Research Institute on the structure of sea ice, and the use of sonar to count fish in the Columbia River for the Department of Interior. One commercial aspect of our work is the appearance on the market of hand-held sonar for skin divers and sonar equipment for fisherman. NUWC test facilities are available to all Government agencies and contractors.

I believe the only measure of effectiveness in R&D must result from comparisons on a competitive basis. This means that we need more than one laboratory in each field of endeavor which is important to government operations; or more realistically, we need two or three groups of laboratories, each having a broad scope of activities extending all the way from research through development, testing and evaluation, and limited production of the type needed to provide guidelines for large scale industrial production. Competition between these laboratories, or groups of laboratories, should be encouraged and the record of their accomplishmentments evaluated. Our abilities to satisfy society's needs are judged by

competition and rewarded by success or failure. This process provides high incentives and high motivation. People work best when they feel they have set their own objectives and have control of the process. The general management can be very loose and competition can provide opportunities both to try and to judge organizational procedures. Such management will be successful only for laboratories with a broad mission since parts of the total process cannot be productive by themselves (i.e., pure research without application is never profitable); the final product is the most reliable measure of productivity.

PRACTICABILITY OF PRESENT METHODS FOR INTERAGENCY SUPPORT OF R&D

BASED ON YOUR EXPERIENCE, HOW WOULD YOU RANK IN ORDER OF PRACTICABILITY VARIOUS WAYS IN WHICH THE LABORATORY OF ONE AGENCY MAY PARTICIPATE IN THE WORK OF ANOTHER AGENCY? YOU MIGHT COMMENT ON JOINT UNDERTAKINGS, INTER-AGENCY TRANSFER OF FUNDS, DIRECT AGREEMENT BETWEEN THE OUTSIDE AGENCY AND THE LABORATORY AND OTHER WAYS.

In my opinion, the most practical method of supporting inter-agency research and development is through a direct agreement between the laboratory and the outside agency. Joint undertakings and interagency transfer of funds, while quite feasible in principle, tend to become enmeshed in workings "of the system" to the point where a great deal of program effort is absorbed by administrative and communication problems unless a central focal point exists. When a program needs integrated planning, the existence of a planner or a master architect seems essential. This man should have the following characteristics:

1. Technical competence.
2. Dedication and enthusiasm for the job.

3. Planned availability for the duration of the job.

4. Knowledge of, and control of, the needed resources including supporting laboratory efforts.

If such a man is not available, the programs will proceed better in smaller units without overall coordination. A study of our successful and unsuccessful projects as related to the continuity of management might serve to enlighten this point.

CONCLUSION

In conclusion, gentlemen, I feel that in the management of Federal laboratories the following operational principles should be retained:

a. Self-determination of the direction of a laboratory's programs by the skillful use of "independent funds" and friendly inter-laboratory competition.

b. Reward for achievements, and discipline for ineffectiveness through competition.

I propose also that the management of Federal laboratories:

a. Extend and augment the concept of laboratory centers of excellence with broad missions such as the Naval Weapons Center, Naval Undersea Warfare Center, Naval Ship Research and Development Center, and Naval Command Control Communications Laboratory Center.

b. Extend and augment councils of laboratory directors to promote better interlaboratory communications and understanding of laboratory capabilities.

c. Use the methods of the Navy's Vietnam Laboratory Assistance Program to bring technical problems directly to people with the requisite technical competence for resolution of the problems.

d. Ask laboratories to review their contractual actions for cross-service to other laboratories; (i.e., reward interlaboratory cooperation)

e. Propose legislation that will decrease the lead time required to procure facilities to support research, test and evaluation effort.

f. Continue to make laboratories available to other agencies so long as this effort does not exceed 10% of the total effort of the laboratory.

g. Give the Laboratory Director the authority to decide on proper balance between programs.

h. Consider co-location of facilities by Federal agencies in order to broaden the experiences of each.

BILL McLEAN ON LABORATORY MANAGEMENT

(Dr. Wm. B. McLean, Technical Director, Naval Undersea Warfare Center, appeared on 27 March 1968 before the House Subcommittee on Science, Research and Development. Long a leading spokesman for Navy laboratories, he was the only Defense laboratory director invited to testify at the Subcommittee's hearings on the utilization of federal laboratories. The following excerpts from Dr. McLean's testimony should be of special interest to the Navy R&D community. —Ed.)

On Laboratory Mission

If the government were to establish clearly defined, narrow, and exclusive missions for its laboratory organizations, it would eliminate competition and would soon be faced with the complete coverage of all areas of technical endeavor by organizations convinced that nothing can be changed and that all new projects are worthless.

On System Design

The concept of a single responsible designer for systems as complicated as those of our modern weapons has not been employed frequently in our current military designs. If we want to achieve simple, integrated design, we should employ the concept of appointing a single master designer for each system, who would execute his responsibilities in a manner similar to that of the master architect of a building. ...(An outstanding example of such an architect is Admiral Levering Smith in the Polaris program.) ...This man should have the following characteristics:

- Technical competence
- Dedication and enthusiasm for the job
- Planned availability for the duration of the job
- Knowledge of, and control of, the needed resources including supporting laboratory efforts.

If such a man is not available, the programs will proceed better in small units without overall coordination.

On Independent Research and Independent Exploratory Development (IR&IED)

Our objective in research should be to make sure that our work is as near the frontiers of knowledge as is possible; that we are working in those areas where we have strong interests and the proper tools to carry out the research; and that we are continually searching for a better understanding of nature and are always on the lookout to find discrepancies in our known knowledge which will lead us to interesting new possibilities.

I believe that one of the most important functions of the laboratory director is to apply (IR&IED funds) in such a way as to investigate new ideas of the laboratory personnel. The ability to act quickly on new suggestions is very important in maintaining the morale of scientific people.

In selecting from ideas, which are always more numerous than the funds available, the (laboratory) director must have clearly in mind the needs of his parent organization and the state of technology. He should give highest priority to suggestions that will provide developments which the organization will need in the next 5 years and to experiments which attack critical questions on the forefronts of technology.

...The most unbiased judgment of a director's use of independent funds is the degree to which the laboratory secures development projects from the parent organization based on information and demonstrations made possible by independent work.

Of the various methods of supplying IR funds, I would favor the one which assigns a certain percentage of the total budget of the laboratory for this purpose. The rewards for careful use of the funds to guide developments toward things which are needed by the sponsoring agencies will, in this case, be automatic.

On Workload

My own experience would indicate that people can perform at rates at least an order of magnitude (factor of 10) different depending on interest or lack of it in the work being undertaken. Interesting programs are easy to add to an already full workload. ...I believe that only by overloading development groups can we be sure of maximum return.

On Change in Laboratory Organization

The continuing resource and essential product of government laboratories is the accumulated experience of its people. The organizational problem is to continue to generate changes which will allow this experience to be applied in new areas. Organizational changes are needed at a rate matched to the effective life cycle. For R&D laboratories, changes at rates less than 5 years will stop productivity and at more than 20 years will promote atrophy. A federal policy which would ensure that the changes in laboratory management and mission are slower than 5 years and more rapid than 20 might be considered desirable for maximum return on the investment made in creating "experienced laboratory people."□

FIT THE JOB TO THE MAN

It is essential that we realize that poor performance in a leadership position is likely to be as much the function of the leadership situation which the organization provides as it is the function of the individual's personality structure. An alternative to discarding the poorly functioning leader is then to engineer the organizational dimensions of the leadership job so that the specialist can function effectively not only as a technical expert but also as a manager and leader. In view of the increasing scarcity of highly trained executive manpower, an organizational engineering approach may well become the method of necessity as well as of choice.

From *A Theory of Leadership Effectiveness*. by Fred E. Fiedler, Department of Psychology, University of Illinois, Urbana, Ill., McGraw-Hill Book Company, Inc., 1967. □

Managing and Fostering Creativity

This section contains the following speeches in chronological order:

"Management and The Creative Scientist," presentation as member of a panel entitled "It Depends Upon Where You Sit," Thirteenth National Conference on the Administration of Research, hosted by Rensselaer Polytechnic Institute, Manchester, Vermont, 28-30 September 1959

Admitting that "the creative scientist is a nuisance, causing untold trouble for administrators and those who would like to use his services," McLean nevertheless stresses the need to nurture creative people because "once in a great while the breakthroughs made possible by continual search may completely revolutionize our methods and procedures." He lists the factors that inhibit creative action in an R&D establishment, factors that are likely to surface when an organization stresses productivity at the expense of risk-taking.

Remarks on the proper climate for research, all-hands meeting, Research Department, Naval Ordnance Test Station, China Lake, California, 6 February 1961

McLean encourages Research Department employees to pursue new ideas with enthusiasm and to communicate the results of these experiments with the development people.

"Promoting the Creative Instinct Through the Educational System," presentation to Cactus Branch, California Association for Childhood Education, 13 May 1961

McLean discusses "how we might establish the educational system in such a manner as to promote, rather than to inhibit, the creative instinct." He suggests that teaching machines should be developed that "create as much involvement of the senses as possible with a high degree of simulation of reality." The teacher would be more important than ever in this saturated learning environment, however, since the machine "can only repeat canned programs and has difficulty introducing indefiniteness, or the need for decision."

"A Technique for Increasing the School's Effect on the Creative Activities of Students," presented to members of the California Association of School Administrators, 18 October 1961

In a longer version of the speech described above, McLean describes teaching machines as promising tools to help the educational system "encourage students to try novel approaches, rather than subject them to the pressures for conformity which are necessary for the rapid assimilation of knowledge under the system we are now using."

Paper on fostering creativity in childhood education, Conference on Education for Creativity in Sciences, New York University, New York, 13-15 June 1963

McLean makes an interesting contrast between the system of rewards used in NOTS porpoise research and "some of the negative processes which go into the training of our children." He suggests that learning can be made a pleasure rather than a duty by employing teaching machines and by organizing classes into real working groups.

Presentation on invention, Conference on Fostering and Rewarding Invention in the Company, the Government and the University, sponsored by the Patent, Trademark, and Copyright Foundation, George Washington University, Washington, D. C., 20 June 1963

McLean describes some of the protective systems that large organizations typically set up to discourage innovation. An "amazingly effective loophole in the armor against change," however, is provided by exploratory funding, which "gives the inventor a chance to get started and demonstrate that his idea will work."

Paper Presented by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California, at the

THIRTEENTH NATIONAL CONFERENCE ON THE ADMINISTRATION OF RESEARCH Rensselaer Polytechnic Institute - Host, September 28,29,30, 1959 Equinoz House, Manchester, Vermont, as a

Member of a Panel entitled "IT DEPENDS UPON WHERE YOU SIT" which considered the relationships between research organizations and higher management as seen through the eyes of the boss (the entrepreneur); as viewed from the standpoint of the scientists; and as observed from the outside by the business management consultant and management scientist.

MANAGEMENT and the CREATIVE SCIENTIST

by WM. B. McLEAN

The creative scientist views management in a manner which I believe is different than that of the productive scientist. In this article, I shall attempt to define some of the factors which influence the creative scientist and to describe how he views management.

The creative scientist is a rare type of individual representing only a small portion of the total population and even a small fraction of scientists. He is a nuisance, causing untold trouble for administrators and those who would like to use his services. However, in the proper circumstances and climate, his output may be very valuable. Our organizational and management advances may soon make him extinct and, for that reason, I believe we should study him while we can.

The number of people who start life with a high degree of creative ability and creative drive is unknown because the forces of society begin so rapidly to act to repress and restrain the curiosity and experimental operations of the young child. When he is told "stop asking questions", "don't touch", "why did you break that", he soon learns that the "new" and "different" can be tried only in the face of strong social opposition.

As the child enters school, he learns that things are right because "teacher says so". He must adjust his conduct to the rules, and it is much too complicated to explain to him why the rules exist. Military training teaches him that conformity is essential to self-preservation. To disobey, or question orders, can bring not only his own downfall, but that of his friends.

The graduate school in college is almost the first time that most of our children learn that not everything is known--that there are vast areas of new information to be explored, and untold new things to try. With a lifetime of training in obedience and conformity behind them, it is not very surprising that few of our young people still retain their early curiosity and still have the inner drive to seek out and try the new and unpopular things.

We have a very effective filter to weed out the merely mildly creative people, and we should therefore expect that the residue who continue to want to explore will be the lunatic fringe, the congenital non-conformists, the people to whom any regulations are unacceptable. This type of person is apparent not only in science, but also in literature, art, acting, or any other field of creative ability. These people tend to be a nuisance, or worse, in any smooth-running organization. They want change just to be different. They question even the most obvious actions and take deep delight in finding discrepancies. If they could only learn that such things as company policy might just as well be accepted on faith, life would be so much easier for all of us.

The creative person is work-oriented, rather than company or organization oriented. He is therefore hard to manage. If you ask him to stop doing some particular job he happens to be interested in, he is very likely to leave your organization to find another one which will support the work which has captured his interest. For this reason, a large percentage of the creative scientists collect in universities, "our worst run businesses", where no one cares what type of research they are doing.

Since a creative scientist is so hard to fit into an organization, why should an administrator ever bother to hire one? It seems to me that, if we can eliminate competition between groups by properly defining the functions of the groups, no administrator in his right mind would tolerate the potentially upsetting influences of these creative people who are always looking for new and different ways to do things. However, in the face of competition, there is always the danger that the continual searching, the everlasting trying of new things, will result in something better. Therefore, it is not safe to leave innovation entirely to the competition because it has been shown that once in a great while the breakthroughs made possible by continual search may completely revolutionize our methods and procedures. We must remain as ready for change as our competition, recognizing, of course, that this readiness is expensive and must necessarily reduce company profits.

The number of creative individuals throughout history has shown a tendency toward large variations, expanding after times of dissatisfaction and revolution when change is not only acceptable but desired, and contracting when peace has been established and things are going well. When people are happy with their operations, competition is limited, and the organizational system is the best in the world, why should we want to change it? If history is a good guide, we should expect creativity in Russia and China to be rising, as it falls in the United States. Maybe this is good and will result in a higher standard of living, but, if we feel it is important to reverse this trend, we need to study the creative scientist and try to make those changes that will promote his more effective operation.

The factors which help a creative scientist produce are hard to define because they seem to reduce so quickly to the statement he makes so often, "just leave me alone". However, he will produce best if he feels he has an important job, that he has a chance for major gain (preferably unexpected), and if he has the proper tools to do the job.

On the other hand, due to much more experience in the area, we find it less difficult to define those factors which will inhibit creative action. We can rapidly change a creative organization into one doing only routine productive work if we

a. coordinate work carefully to avoid duplication.
(Everything new can be made to look like something we have done before, or are now doing.)

b. keep the check reigns tight; define missions clearly; follow regulations.
(Nothing very new will get a chance to be inserted.)

c. concentrate on planning and scheduling, and insist on meeting time scales.
(New, interesting ideas may not work and always need extra time.)

d. ensure full output by rigorous adherence to the scheduled workday.
(Don't be late. The creative man sometimes remembers his new ideas, but delay in working on them helps to dissipate them.)

e. insist that all plans go through at least three review levels before starting work.
(Review weeds out and filters innovations. More levels will do it faster, but three is adequate, particularly if they are protected from exposure to the enthusiasm of the innovator. Insist on only written proposals.)

f. optimize each component to ensure that each, separately, be as near perfect as possible.
(This leads to a wealth of "sacred" specifications which will be supported in the mind of the creative man by the early "believe teacher" training. He will then reject any pressures to depart from his specifications.)

g. centralize as many functions as possible. (This creates more review levels and cuts down on direct contact between people.)

h. strive to avoid mistakes. (This increases the filter action of review.)

i. strive for a stable, successful, productive organization. (This decreases the need for change and justifies the opposition to it.)

On a national scale, we are making great progress in most of these areas of reducing creativity in order to be more productive. Our management principles for greater productivity are based on strict adherence to the reduction of change. We have achieved and undoubtedly will achieve even greater productivity, but will this productivity lead to safety of the nation under the new and rapidly changing ground rules for the conduct of war, or the influencing of people, which are being forced upon us?

I sometimes wonder if one of Russia's greatest advantages in the kind of economic conflict she has so clearly declared to be her goal is not the fact that she still needs things. Our great productivity prevents us from accepting goods from others and therefore bars us from trading with them. Our great independence makes concern about others difficult and therefore the exertion of influence upon them negligible.

I would like to conclude with the radical and unproven thought that we might be able to sacrifice some productivity in order to try new things in our struggle to stay ahead of a very versatile and clever opponent.

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ALL HANDS MEETING, RESEARCH DEPARTMENT, COMMUNITY CENTER, 6 FEBRUARY 1961

REMARKS BY

WM. B. McLEAN
Technical Director

Today, I would like to introduce Dr. Waring to you and, at the same time, give some personal comments concerning my beliefs with respect to the future orientation of the Station's work and the importance of research with respect to achieving the over-all objectives of the Station.

IMPORTANCE

I believe that if the government is to have the responsibility for the military operations of the country, it must have the capability to come up with new ideas for equipment, to demonstrate that they are feasible, and to provide the educated background against which the performance of various contracting agencies can be judged. This means that the government laboratories throughout the country should undertake the leadership with respect to delving into the new things which will be required by the government in the prosecution of those programs for which it is responsibile.

I believe that you will all agree that our present technology is expanding rapidly. I like to think of research as being those operations which occur at the borders of the known area of knowledge and which are concerned with the penetration into the surrounding infinitude of the unknown. As the realm of the known increases, it is obvious that the total number of areas of research which can be undertaken will also increase.

OBJECTIVES

I am of the opinion that research is never a job which can be completed, but will continually expand as more positive results become available. It is, therefore, obvious that no single organization can ever attempt to cover all possible areas of research, even in a very superficial manner. I believe it should be our objective in research to make sure that our work is as near the frontiers of knowledge as is possible; that we are working in those areas where we have strong interests and the proper tools to carry out the research; and that we are continually searching for a better understanding and are always on the look-out to find discrepancies in our known knowledge which will lead us to interesting new possibilities.

MANAGEMENT

The management of research has now become a national problem. We hear a great deal about planning research in such a way as to avoid gaps in coverage, about trying to make sure that all research will be profitable, and about the necessity to avoid duplication. It is my belief that it will always be impossible to cover all possible areas of research. The best we can do in the management of research is to find people who have a genuine interest in carrying out research activities and try to stimulate discussions across organizational lines in order to promote the generation of new ideas. I hope we can forget about clearly defined missions and the avoidance of duplication. No well-informed and sensible research man is going to

deliverately do the same kinds of work which are being carried out in another organization. The more the planning of research can be delegated to the man close to the work, the more likely it is that it will approach the boundaries of the known realm of knowledge.

As a man responsible to others for the function of managing research, I believe it is my duty to try to understand what is going on well enough to be able to communicate the more important accomplishments. I need to be in a position to understand and accept new ideas and eventually to judge the ability of people to carry out the work which they are interested in doing. In this type of judgment I would place first priority on the interest and enthusiasm which a man shows in the work which he is doing and, second, on his skill in visualizing and planning the crucial experiments which must be carried out in order to check new theories or hypotheses.

CLIMATE AND ATMOSPHERE

To summarize, it would seem to me that the proper climate for good research is an organization equipped with good tools, free communication between various members of the group, (including the rest of the Station), mutual respect, and an interest in new ideas. In such conditions, it is very difficult to imagine that the research will not be useful, particularly to an organization whose objectives are as broad as those represented at NOTS. I don't intend to imply by this that the research man should plan his work so that it will obviously be useful, but I do believe that any really new information which comes out of the research work will, without doubt, open many new avenues of approach to the imaginative development man. We should not try to make research work useless.

RESPONSIBILITIES

I believe strongly in the fact that we should give our research people the maximum freedom possible to prosecute those things which they believe important. A large measure of freedom, however, does imply some definite responsibilities which the research man must assume. The first of these, I think, is the responsibility to avoid things that are in some sense trivial. Secondly, I believe any self-respecting research man should try to do work in his field which he fully expects to be the best which is being done in the country. With freedom to choose fields, and with knowledge of what is going on throughout the world, this should always be possible. When we do second-rate work, it should only be by accident. The final responsibility of research, I believe, is the communication of the significance of the results which have been accomplished. If research is to be supported as a group activity, then the results of the research must be available to more people than just the man who is doing the work. We have many methods of communications and I believe all of them are valuable. We publish reports; we give lectures; we teach classes; we have informal discussions; we consult, and we advise. All of these are valuable to the progress of the organization.

NOTS, as an organization, has the objective of leading the way toward new and useful military equipment for the country. This objective can be

accomplished only if the development work is based upon an intimate contact with all of the new information being produced in the research areas both at NOTS and throughout the rest of the world. I believe the Research Department represents our contact with this information.

I believe we are very fortunate to have Dr. Waring with us for the next year and I am sure he will be of great assistance to us in promoting a better understanding of the importance of research and its accomplishments.

PROMOTING THE CREATIVE INSTINCT THROUGH THE EDUCATIONAL SYSTEM

by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California. Presented to the Cactus Branch, California Association for Childhood Education, 13 May 1961.

I have been asked to repeat a paper on the subject of creativity which I had prepared about two years ago for the Conference on Administration of Research. At that time I was particularly concerned with the tremendous pressures which society exerts on the individual from the time of birth onward which act to prevent creative activities. I pointed out that the schools were strong instruments in this process caught by their great desire to pass on to each student the accumulated knowledge of our culture. Our cultural knowledge is now so vast that the task of transferring it from one individual to another leaves little time for investigating the interesting pathways and byways which might stimulate the creative instincts inherent in most of us.

In this lecture I also pointed out that we quite often use the words "creative" and "productive" as though they were synonymous. In one sense they are, but in the sense I have been using them it is probably true that creative activities tend to hamper production because they introduce changes which cannot help but slow down the productive process. On the other hand, those techniques and procedures which tend to increase the productive output, such as good organization, well defined tasks, and the other tools generally credited to good management, are just those devices which are guaranteed to inhibit the creative operation defined in the sense of producing change. Our language may lead us to great confusion in our management actions if we do not distinguish between <u>creativity</u> (those things which one does to make himself adaptable to a changing environment) and <u>productivity</u> (those things which he does to satisfy the wants and requirements which arise in an environment which may or may not be changing.)

However, instead of repeating this lecture tonight, I would like to advance to a discussion of how we might establish the educational system in such a manner as to promote, rather than to inhibit, the creative instinct and to discuss what new technical tools and concepts we now have available which might aid in setting up a more interesting educational system.

I believe that all of you in the teaching profession recognize that there are two parts to the educational system. I have heard considerable discussion of the importance of subject matter versus method, of subject courses versus education courses, and of the oldfashioned method of concentrating on learning versus the progressive methods which will teach people how to use their knowledge and to get along with each other. In fact, the arguments on both sides of these questions at times becomes so violent that I approach a discussion of them with this group with considerable trepidation and the warning of my friends that this is a good way to start a fight.

Nevertheless, I should like to propose for your consideration that our technical equipment has now advanced to the point where teachers may soon forget about subject matter because it can be taught more rapidly, more effectively, and more accurately by the use of machines than it can by the use of teachers, no matter how skilled they may be. If such machines can be built, and I will say a little more about techniques which make them seem

to be reasonable, then both the teachers and the pupils will have a great deal more time available to concentrate on those activities which tend to stimulate the creative instinct latent in most people. Educators can set up group projects in which each of the students can apply the knowledge which he has just learned from the machines. The teachers can create situations in which the student can learn that most questions which he will meet in real life do not have a single answer, as contrasted with the kind of definite information which he has gotten on subject matter from machines. In general, the teachers and students can study group dynamics and group processes and work to create the emotional stability and the acceptance of differing ideals and values, which in the long run are those things which tend to make an individual a happy and useful member of a group organization such as the human society.

Inasmuch as my education is primarily technical, I would be out of my field if I were to concentrate tonight on how you might best utilize the time, which teaching machines will make available, to promote better group adjustment and mental health. You are all better equipped in this field than I.

I would like to devote more of my time to the technical problems of making subject matter available by suitable canning. I do not mean by this to belittle the importance of subject matter by relegating it to the role of the canned approach. This type of knowledge represents the accumulated experience of the human race. As the world has achieved each improved technique in passing such information on, we have achieved an advancement in the rate of increase of cultural progress. The invention of language represents the first step in this series. Writing extended the transmission of information through time. Printing spread it out through greater numbers of contacts. The phonograph and radio added voice inflections and expressions not contained in the written words, and the addition of motion pictures and television have allowed us to transmit information by sight and sound nearly instantaneously to the whole population of the Earth, if they are interested. The new ideas so generated are becoming truly staggering. Our problem in education is to distill this information and present it in such form that each individual can make increasing use of it in a limited lifetime, which unfortunately has not increased in length as fast as the information available has expanded.

Present theory shows that the more completely all perceptive organs are involved in the reception of information, the more immediately it will be available for recall, and the shorter the time required to assimilate any degree of factual information. I have been impressed by the emotional involvement which results simply by including the peripheral vision stimuli in the Cinerama motion pictures. However it may come about, I am sure that my recall for scenes in the Cinerama pictures, such as the roller coaster ride or the bobsled rides, where my stomach became involved as well as my sight and sound, remains completely available for recall long after other pictures have been forgotten.

One of the first principles, therefore, of the advanced teaching machine should probably be to create as much involvement of the senses as possible with a high degree of simulation of reality. Stereoscopic, wide angle, color, motion pictures, together with binaural recordings, are certainly now technically feasible, particularly if they need to be projected only for one person. The recording of tactile stimuli has not yet been accomplished, but since they represent electrical signals traveling along nerve fibers, this may some day prove feasible. Nevertheless, with the tools we now have, let us consider one of the simplest possible teaching machines from the standpoint of programming. This might be one constructed to acquire an understanding of foreign languages. On the wide-angle, 3D screen, a student could be made to feel that he was arriving in a foreign country where he would see and hear people talking the foreign language he would like to learn. In this presentation, these people might turn to him and ask him questions. His appropriate responses would be whispered to him at first as though they were arising inside of his head. Simultaneously, the printed words, in both the foreign language and in English , would appear as subtitles in the pictures. As the student progresses in responding to his parts of the conversation, he can increase or decrease the volume and the delay with which his internal prompter supplies him with the needed information. I think it is obvious that such a language machine would teach not only language well, but it would also allow the student to see the actual scenes, the geography, the social customs, and perhaps the history of the country which he is visiting. As a military device, one might visualize such machines for use on a troop transport during the time the troops are enroute from this country to any local trouble spot. How much more acceptable they would be in such a country if they all arrived knowing the basic words they would need, all familiar with the local geography, the local customs, the important taboos, and the social usages of the people they were to meet.

In this system we have a technique which might be described as recording experiences in such a manner as to allow students to relive them as they desire. If this is to be a useful teaching process, it depends on the assumption that only a small percentage of our actual experiences in life are those which contribute to the learning process. By careful selection of these significant experiences, it should be possible to build up knowledge in a multitude of areas in a form which could be most rapidly assimilated and pass on to other people. It is also obvious that such a technique allows the incorporation of many ideas at the same time. It would represent pre-programmed progressive education but on a basis where each student could select his own rate of progress. Machines also have infinite patience and no emotional response.

This kind of tool, however, raises some interesting problems. Suppose all of our children are subjected to the same group of experiences. Will this tend to produce people all in the same mold? I have a feeling, accepted without proof, that it will not. Each person will see different things in a

given scene even early in life. I believe that man's responses are neither entirely learned, or entirely inherited. The pathways in his brain must be both inherited and constructed as a response to the stimuli of experience. Some species, such as bees, ants, or wasps, and perhaps birds, would tend toward having the majority of the brain patterns inherited. Man, because of his greater ability to adapt, must have fewer inherited pathways and more which must be modified as a result of experience. Therefore, to the degree that man is adaptable by experience, teaching machines can certainly have the possibility of danger of introducing conformity, and we should avoid having a completely canned educational program. To the degree that we inherit differences, our responses to similar stimuli will be varied.

We should also be concerned about the political implications. Isn't it possible that in learning a foreign language too much of the political institutions and feelings of the country whose language is being studied might be instilled? I think that this worry is justified and needs careful consideration. Any new tool for disseminating knowledge will bring with it the strain of spreading new or different ideas. Some of these will be socially acceptable, and others will not. At this point we need the teacher. The machine can only repeat canned programs and has difficulty introducing indefiniteness, or the need for decision. Programs expressing all types of political ideas will undoubtedly become available. The teacher and the social group must provide the opportunity and the stimulus for exercising the knowledge and evaluating the varied experience which can be presented by the teaching machine.

In the future the ideal class might be operated very much like science foundations are today. Groups of students would work on projects of various kinds which both make use of the knowledge they have learned and provide the stimulus to seek new areas of knowledge which will be available through other machine programs. As knowledge pyramids upon us, the inability to learn everything will become more and more apparent. Our ability to advance in a multitude of directions will be realized only if each person can learn to select those areas of knowledge which are most interesting and, therefore, most useful to himself. This should not lead to narrow specialization for the easy availability of canned knowledge should reduce the need for specialization and make it possible for each student to go into many fields if his interests so lead him.

If the teachers can relax during the time that the children are experiencing their lessons via the teaching machine, then they will have the time to do the creative effort needed to think of new projects which will be true explorations of the unknown.

In dealing with new and real problems, we can expect the members of the future learning institute will achieve adaption to society through the very emotionally satisfying experience of creating new artifacts or tools for use by that society and will feel acceptance into the group as their ideas become of use.

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A TECHNIQUE FOR INCREASING THE SCHOOL'S EFFECT ON THE CREATIVE ACTIVITIES OF STUDENTS

(An Address to Members of the California Association of School Administrators by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California, 18 October 1961)

I have been concerned for some time about the tremendous pressures which all societies seem to exert on the individual members of the society to prevent creative activities. The process of producing conformity starts at birth and seems to continue with increasing pressure through life. Schools in particular are strong instruments in this process because of the tremendous amount of knowledge which has been accumulated by our culture which must be passed on to individuals in a relatively short time. The problem of transferring information is so time consuming that the investigation of interesting byways which might stimulate the inherent creative instinct is missed for lack of time. It is somewhat difficult to define exactly what is meant by the creative instinct, but most of us understand it as it applies to art, music, and things of a non-material nature. In the material field we often use the words creative and productive as though they were synonymous. However, in the sense that I have been using them, they seem to me to be competing processes. Creative activities tend to hamper production because they introduce changes which in essence, slow down the productive process. On the other hand, techniques and procedures which tend to increase the productive output, such as organization, well defined tasks, and the other tools generally credited to good management are exactly the devices which will guarantee to inhibit the creative operation which comes into being only when a need for change exists.

I would like to discuss how we might change the educational system in such a manner as to encourage students to try novel approaches, rather than subject them to the pressures for conformity which are necessary for the rapid assimilation of knowledge under the system we are now using. We have new technical tools and concepts for teaching which will allow us to achieve the mechanical aspects of learning in a relatively short time and will free the remaining time to investigate interesting uses of the knowledge which we have accumulated.

I believe that all of you in the teaching profession recognize that there are two parts to the educational system. I have heard considerable discussion of the importance of subject matter versus method, of subject courses versus education courses, and of the old-fashioned method of concentrating on learning versus the progressive methods which will teach people how to use their knowledge and to get along with each other. In fact, the arguments on both sides of these questions at times become so violent that I approach a discussion of them with a group such as this with considerable trepidation and the warning of my friends that this is a good way to start a fight.

Nevertheless, I should like to propose for your consideration that our technical equipment has now advanced to the point where teachers may soon forget about subject matter because it can be taught more rapidly, more effectively, and more accurately by the use of machines than it can by the use of teachers, no matter how skilled they may be. If such machines can be built, and I will say a little more about techniques which make them seem to be reasonable, then both the teachers and the pupils will have a great deal more time available to concentrate on those activities which tend to stimulate the creative instinct latent in most people. Educators can set up group projects in which each of the students can apply the knowledge which he has just learned from the machines. The teacher can create situations in which the student can learn that most questions which he will meet in real life do not have a single answer, as contrasted with the kind of definite information which he has gotten on subject matter from machines. In general, the teachers and students can study group dynamics and group processes and work to create the emotional stability and the acceptance of differing ideals and values, which in the long run are those things which tend to make an individual a happy and useful member of a group organization such as the human society.

Inasmuch as my education is primarily technical, I would be out of my field if I were to concentrate on how you might best utilize the time, which teaching machines will make available, to promote better group adjustment and mental health. You are all better equipped in this field than I.

I would like to devote more of my time to the technical problems of making subject matter available by suitable canning. I do not mean by this to belittle the importance of subject matter by relegating it to the role of the canned approach. This type of knowledge represents the accumulated experience of the human race. As the world has achieved each improved technique in passing such information on, we have achieved an advancement in the race of increase of cultural progress. The invention of language represents the first step in this series. Writing extended the transmission of information through time. Printing spread it out through greater numbers of contacts. The phonograph and radio added voice inflections and expressions not contained in the written words, and the addition of motion pictures and television have allowed us to transmit information by sight and sound nearly instantaneously to the whole population of the earth, if they are interested. The new ideas so generated are becoming truly staggering. Our problem in education is to distill this information and present it in such form that each individual can make increasing use of it in a limited lifetime, which, unfortunately, has not increased in length as fast as the information available has expanded.

Present theory shows that the more completely all perceptive organs are involved in the reception of information, the more immediately it will be available for recall, and the shorter the time required to assimilate any degree of factual information. I have been impressed by the emotional involvement which results simply by including the peripheral vision stimuli in the Cinerama motion pictures. However, it may come about, I am sure that my recall for scenes in the Cinerama pictures, such as the roller coaster ride or the bobsled rides, where my stomach became involved as well as my sight and sound, remain completely available for recall long

after other pictures have been forgotten.

One of the first principles, therefore, of the advanced teaching machine should probably be to create as much involvement of the senses as possible with a high degree of simulation of reality. Stereoscopic, wideangle, color motion pictures, together with binaural recordings, are certainly now technically feasible, particularly if they need to be projected for only one person. The recording of tactile stimuli has not yet been accomplished but, since they represent electrical signals traveling along nerve fibers, this may some day prove feasible. Nevertheless, with the tools we now have, let us consider one of the simplest possible teaching machines from the standpoint of programming. This might be one constructed to acquire an understanding of foreign languages. On the wide angle, 3D screen, a student could be made to feel that he was arriving in a foreign country where he would see and hear people talking the foreign language he would like to learn. In this presentation, these people might turn to him and ask him questions. His appropriate responses would be whispered to him as though they were arising inside of his head. Simultaneously, the printed words in both the rogeign language and in English would appear as subtitles in the pictures. As the student progresses in responding to his parts of the conversation, he can increase or decrease the volume and the delay with which his internal prompter supplies him with the needed information. I think it is obvious that such a language machine would teach not only language well, but it would also allow the student to see the actual scenes, the geography, the social customs, and perhaps the history of the country which he is visiting. As a military device, one might visualize such machines for use on a troop transport during the time the troops are enroute from this country to any local trouble spot. How much more acceptable they would be in such a country if they all arrived knowing the basic words they would need, all familiar with the local geography, the local customs, the important taboos, and the social usages of the people they were to meet. Such a machine might provide the insight needed in training Peace Corps personnel so that they would not be so surprised in arriving in a foreign country.

In this system we have a technique which might be described as recording experiences in such a manner as to allow students to relive them as they desire. If this is to be a useful teaching process, it depends on the assumption that only a small percentage of our actual experiences in life are those which contribute to the learning process. By careful selection of these significant experiences, it should be possible to build up knowledge in a multitude of areas in a form which could be most rapidly assimilated and passed on to other people. It is also obvious that such a technique allows the incorporation of many ideas at the same time. It would represent pre-programmed progressive education, but on a basis where each student could select his own rate of progress. Machines also have infinite patience and no emotional response.

Some feel that machines should be built to respond like teachers. I doubt this. Teachers emotions and evaluation are needed in group adaption but probably inhibit the learning process.

This kind of teaching tool, however, raises some interesting problems. Suppose all of our children are subjected to the same group of experiences. Will this tend to produce people all in the same mold? I have a feeling, accepted without proof, that it will not. Each person will see different things in a given scene even early in life. I believe that man's responses are neither entirely learned, nor entirely inherited. The pathways in his brain must be both inherited and constructed as a response to the stimuli of experience. Some species, such as bees, ants, or wasps, and perhaps birds, would tend toward having the majority of the brain patterns inherited. Man, because of his greater ability to adapt, must have fewer inherited pathways and more which must be modified as a result of experience. Therefore, to the degree that man is adaptable by experience, teaching machines can certainly have the possibility of danger of introducing conformity, and we should avoid having a completely canned educational program. To the degree that we inherit differences, our responses to similar stimuli will be varied. This is a paradox of a sort.

We should also be concerned about the political implications. Isn't it possible that in learning a foreign language too much of the political institutions and feelings of the country whose language is being studied might be instilled? I think that this worry is justified and needs careful consideration. Any new tool for disseminating knowledge will bring with it the strain of spreading new or different ideas. Some of these will be socially acceptable, and others will not. At this point we need the teacher. The machine can only repeat canned programs and has difficulty introducing indefiniteness, or the need for decision. Programs expressing all types of political ideas will undoubtedly become available. The teacher and the social group must provide the opportunity and the stimulus for exercising the knowledge and evaluating the varied experience which can be presented by the teaching machine.

In the future, the ideal class might be operated very much like science foundations are today. Groups of students would work on projects of various kinds which both make use of the knowledge they have learned and provide the stimulus to seek new ideas of knowledge which will be available through other machine programs. As knowledge pyramids upon us, the inability to learn everything will become more and more apparent. Our ability to advance in a multitude of directions will be realized only if each person can learn to select those areas of knowledge which are most interesting and, therefore, most useful to himself. This should not lead to narrow specialization for the easy availability of canned knowledge should reduce the need for specialization and make it possible for each

student to go into many fields if his interests so lead him.

If the teachers can relax during the time that the children are experiencing their lessons via the teaching machine, then they will have the time to do the creative effort needed to think of new projects which will be true explorations of the unknown and will lead to greater adaptability. We might even learn how to govern and live with our weapons.

In dealing with new and real problems, we can expect the members of the future learning institute will achieve adaption to society through the very emotionally satisfying experience of creating new artifacts or tools for use by that society and will feel acceptance into the group as their ideas become of use.

CONFERENCE ON EDUCATION FOR CREATIVITY IN SCIENCES
NEW YORK UNIVERSITY, 13-15 June 1963

Discussion by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California

Last September, I attended the Sixteenth National Conference on the Administration of Research held at French Lick, Indiana. One of the problems of concern involved techniques to provide educational reorientation for our research administrators in order to allow them to keep up with a rapidly changing technological background. We heard about the problems of the natural inertia of people, and the difficulties which organizations face in trying to get their personnel interested in taking refresher courses. The establishment of organizational stresses which would force executives to undertake the work of becoming better educated was discussed. Throughout all of these discussions, the tendency seemed to be to consider education as a hard and distasteful process which, nevertheless, it was our duty to undertake. If we do not have sufficient drive and motivation on our own to keep up with what is going on, then it is our organization's responsibility to force us into the learning process.

I tell my two boys that, like it or not, they have to go to school and become educated so that they will know how to behave as intelligent members of our society. Truant officers enforce the attendance of children at schools until they reach the age of maturity.

On the other hand, the Naval Ordnance Test Station recently contracted with Dr. Keller Breland of Animal Enterprises, Inc., Hot Springs, Arkansas, to help us learn how to train porpoises. Dr. Breland has had extensive experience in training over forty different species of animal which involved thousands of different individuals. It is his experience over this

breadth of subject matter that negative pressures, or punishment, are useful only for the purpose of making an animal stop doing something. If one wants an animal to try something new or be creative, it is necessary to use reward and approval as reinforcing agents whenever the animal moves in the proper direction.

The contrast between training animals through a series of rewarding situations, and some of the negative processes which go into the training of our children, struck me as highly interesting. Is it possible that in our desire to see everyone educated we are introducing negative pressures which tend to make them resist education? And more important, perhaps we are also only producing a minimum response, rather than establishing an environment which will encourage the creativity needed to branch off into new types of learning and behavior.

Suppose we start thinking about education from the standpoint that learning should be a pleasure rather than a duty, and that we should be able to make the presentation of new facts and information at least as demanding of attention as the television programs which now capture such a large fraction of our children's time. It seems to me that education comes in two parts: The first is the access to the accumulated experience of our culture, and the second is the process by which we put our knowledge to work in order to perform useful tasks, or to create new devices and new experiences which will broaden the well being of the whole social group. The first of these tasks is the one which can well be performed by machine teaching of various types. The second task of using our knowledge and creating new things seems to require the kind of motivation which is promoted by group activities. I would therefore propose that our schools and universities might better sponsor creative activities if they were

organized somewhat along the lines of research institutes. The Class group would be one in which people with different backgrounds and different interests could work together toward a common objective. In some cases this objective might be a broad goal, such as improving the standard of living in a given area; in others, it might be a more narrow objective such as getting a better understanding of a particular physical, chemical, or biological phenomenon. It would be recognized that none of the people had all of the knowledge in any field which might be available, but the machine training side of the educational system should be so organized that any particular area of interest could be summarized for any member of the working group who wished to ask questions. This is, of course, the function now being performed by our libraries, but the advance of knowledge has become so rapid that reading is a relatively slow and inaccurate method for the transmittal of information and not well adapted to the demonstration of manual skills.

One would hope that by organizing classes into real working groups the natural interests and abilities of people would assert themselves. Those who are natural craftsmen would learn to supply the manual skills for the support of the group activities. They would concentrate on the machine programs best designed to develop their special interests. Those who are perhaps less skilled manually, but more able to do abstract thinking and planning, would also have the challenge and the resources best suited for the realization of their capabilities. The working groups should organize themselves naturally if enough different types of personalities are available in each group. If not, the educational Dean might encourage some shifts between groups.

Since I am primarily a machine designer, I woudd like to discuss some of the things which I think machines can do to relieve the educational system of the problems relating purely to the transmission of and access to information. With such machines available, we can free the teachers and

the classrooms for the job of training the students to utilize knowledge in a creative manner.

Starting with very young children, we see an amazing motivation to begin to control their environment; first by means of hands and feet, and then by means of any other mechanism which will operate in response to their actions. The child who turns the electric light on and off, or rolls the automatic window of a car up and down, seems to be amply rewarded for his efforts simply by observing the effects which he creates. Dr. O. K. Moore, of Yale University, Sociology Department, has utilized this motivation in order to create a machine which teaches even very backward children to read and write. In this machine, he has coupled a keyboard, lighted letters and words and a loudspeaker to a computer so that the picture and sound of a word or letter are associated for the child. The child is involved in remembering and understanding the associations by causing them to appear through pushing buttons. It would seem that this type of machine, or modifications of it such as the question and answer games, manual coordination games, etc., can be designed to speed up the acquisition of all associative type of information. Our first classroom could perhaps then start at an age before the child is ready for group activities and while he is primarily interested in making things happen. With this type of machine we should have no difficulty in teaching reading, writing, arithmetic, and foreign languages.

The next class of machine which our educational institution will need is one which will present general summaries. These summaries, which should form the background of any educated person, should include such things as history, geography, customs (both native and foreign), music, art, and drama. For this type of subject, it seems to me that capturing and maintaining interest is the prime requirement of the machine for this purpose.

I am impressed by the emotional involvement which can be achieved with moving pictures using the Cinerama approach with peripheral vision and stereophonic sounds. As a hypothesis which has yet to be tested, I would bet that the retention of information, presented in such a manner that one really feels involved, would be enough better than our present educational movies that this type of presentation would well be worth the extra expense of its careful preparation. It can be used for that class of information which everyone needs as a working background, and the extra expense spread over a large general usage.

The final type of machine which we need to develop is one which would be in use throughout our lives and would make readily available to us specific information connected with problems we would like to solve. I believe that our present system of reading the multitude of technical and other publications and periodicals is now inadequate and will become worse. It should be replaced by summaries which will utilize both pictures and sound in order to convey information faster and more accurately. The paid TV system would seem to be an ideal mechanism for making this type of information immediately available to anyone in our modern society. By dialing the proper code number on our television sets, we should be able to achieve access to any information which we would desire from a central storage library. The reproducing system in the library would be designed so that a few digits would get a general summary of an area. The summary would include the additional codes necessary to get more detailed information on any aspects of the area which appear to be of specific interest.

When our universities have available the associative machines, the experience machines, and the reference machines described above, together with the tremendous development of program material which will be required

to make them operate, I think we can look forward to an educational system which will allow all of our group activities to be directed toward exploring the relationships between people, and the use of our knowledge for the generation of new and interesting things. Our people will be able to undertake real problems sooner while their creativity is still high. Their education will also last longer and not have the termination points now sometimes provided by the attainment of degrees. One benefit of this new system should be an aid to the use of leisure time which is becoming increasingly available. If we can learn while we relax, life should be more rewarding. Perhaps we may even come to understand how the human mind performs its coding functions in order to be able to gain direct access to the storage of information without the necessity for the intervention of pictures or words.

PAPER ON INVENTION - Presented by Wm. B. McLean on 20 June 1963 at a Conference on "Fostering and Rewarding Invention in the Company, the Government and the University," sponsored by the Patent, Trademark, and Copyright Foundation of the George Washington University, Washington, D.C.

As an inventor employed by the Government as an administrator, I would like to discuss methods used to encourage and foster the inventive process which we intuitively feel is the basis of our technical success.

One of the facts of life which an inventor must soon learn is that no matter how much the Government may express the need for more creativity and invention, in general any specific invention an inventor would like to propose is likely to be upsetting to an organization as large as the Government. If it is really new, it is likely to lie somewhere between the fields of offices set up to handle specific areas of work. The inventor can expect one of two answers: (1) neither office is interested and suggests he take his idea to the other, or (2) both are interested and become involved in a cognizance fight to see who will gain control of the intermediate area. Either course of action is likely to be upsetting to the inventor unless he is properly equipped with the patience to wait for the dust to settle.

A really novel invention, like the aircraft radar or the atomic bomb, can be tremendously upsetting to a large organization. The organization may have to completely change its methods of doing business, people will be displaced, new training will be required, etc. It is no wonder, therefore, that large organizations naturally develop mechanisms to protect themselves from such disturbances. Some of these protective systems which the inventor may expect are:

(1) The requirement for written proposals before the allocation of any support.

An inventor, if he is successful, has a tremendous degree of self-confidence and enthusiasm for his idea. If the administrator is exposed to this enthusiasm personally, it becomes very difficult to say no. Putting things in writing gives them a dead quality and allows the administrator to find some defensible reason for turning the proposal down--it doesn't meet requirements, would cost too much, won't be ready in time, etc.

(2) Multiple review.

Some administrators have the perversity to like change. They may even have sadistic tendencies and want to see their associates scramble under the impact of a new concept or invention. The large organization can take care of this eventuality by making sure that no funds are expended without going through several levels of review. The more levels that are inserted, the safer the organization will be from the forces of change.

(3) Definitive long range plans.

The more concretely the organization can plan and schedule its future, the more reasonable will be the rational for avoiding anything that will have the chance of changing the future. I am not against plans, but the Government tends to be production-oriented. The planning process, which is very necessary for production, tends to be carried over into research, much to the discouragement of inventors.

(4) An organization develops clearly defined missions for each of its parts.

These serve a highly protective function because the really new and disruptive things tend to come where someone sees a connection between two previously separated fields. If the missions can be made sacred enough, no one in the organization will have time to work on the new proposal. If the idea originates within some branch, it can usually be thrown out or

transferred to another division where it will be safely lost.

(5) Eliminate duplication. Checking for duplication throughout the organization can delay initiation of new work.

Perhaps I am developing the impression that large organizations cannot foster invention. I firmly believe this to be true and find it supported by the fact that productiveness per man, of a creative nature, tends to fall off as the organizational size increases. Mr. Rice confirmed this by his statement earlier that most of the Atlantic Research patents issued while the Company had /50 people. The Government, I believe, has recognized this need for small working organizations for some of its industrial contractors and for its laboratories, and has stopped acting like a big organization relative to invention by providing funds which can be spent at the small organizational level with accounting after the fact rather than before. This gives the inventor a chance to get started and demonstrate that his idea will work. This is an amazingly effective loophole in the armor against change as attested by the large number of effective inventions which have followed this route. It avoids the problem of the inventor becoming tired of selling his idea to the many people who will not understand it. It lets him get started while his enthusiasm is high. It is a dangerous process and the pressures to stop it are strong. I hope we can resist them.

What else can we do in addition to decentralization of approval? We can stop trying to plan inventions. The inventor is motivated rather like an artist. Only a mediocre product can be scheduled. At present, our highest rewards go to the inventor who delivers on schedule. An inventor critics society has not developed comparable to the art critics. Criticism of this sort would do much to stimulate and foster invention.

The USSR is reported to be undertaking an interesting experiment under which such recognition might develop. They are establishing a science city

where various disciplines will be allowed to work together on new ideas devoted to change. We have some of this mixing of disciplines at the Naval Ordnance Test Station. In my opinion the most creative effort occurs after these different specialist groups surmount the language barriers which normally separate them and they begin to communicate with each other.

To summarize, I think invention needs (1) a small organizational size, (2) a mixing of disciplines, (3) some confusion relative to missions of the groups, and (4) the development of an inventor critics association.

Trends in Weapon Requirements

This section contains the following speeches in chronological order:

"Personal Opinions on Weapon Requirements," presentation to the Underwater Ordnance Division, American Ordnance Association, Pasadena, California, 10 April 1957

McLean speculates that the next war will be primarily a naval activity and that the ability to transport supplies and equipment across the ocean will be critical to U.S. success in that war. Areas of need are enumerated as (1) missiles to be launched from submerged submarines; (2) nuclear-powered submarine transport; (3) helicopters to carry supplies; (4) lightweight, inexpensive, individual air transport; and (5) hovering bombs using television cameras.

"Comments on Trends in Weapon Requirements," presentation to the Honorable James H. Wakelin, Assistant Secretary of the Navy for Research and Development, during his visit to NOTS, China Lake, California, 2 October 1959

In an era of nuclear stalemate, McLean suggests, we can "expect a continuing series of international situations in which the United States will . . . resist pressures by the use of conventional weapons." McLean offers several suggestions for improving conventional-weapon capability, including the development of weapons for close-support air-to-ground attack and of rocket-propelled, single-man, expendable transport for the Marines.

Remarks on development of weapons for limited warfare, made to the Senior Personnel Conference, NOTS, China Lake, California, 29 January 1960, and Pasadena, California, 8 February 1960

After outlining some possible techniques by which warfare can be kept limited, McLean discusses possible NOTS roles in developing weapons for limited warfare—in the immediate future when weapons under development would need completion, in the longer range when U.S. technical competence can be demonstrated through exploration of the unknown, and in the distant future when technical knowledge and capabilities achieved through military programs might be applied on "a broader and less destructive basis."

Remarks on requirements for nonnuclear weapons of the future, made in accepting the AOA Blandy Medal, American Ordnance Association Fuze Section, China Lake, California, 24 May 1960

McLean challenges his audience "to find some way to rescue the design of our military equipment from the morass of integration, coordination, centralization, and detailed specifications in which at present it is sinking." Nonnuclear weapons need to be developed, he says, that are simple, low in cost, producible in large numbers, and easy to operate.

"Long Range Research and Development Goals for NOTS," presentation to NOTS Advisory Board, NOTS, China Lake, California, November 1962

Making "informed guesses" on future rules of conduct for military operations, McLean suggests that a delayed-response deterrent system established between the major powers "will prevent the all-out use of force by allowing time for rational responses in the settlement of international difficulties," that nuclear weapons and lethal biological weapons "will exist only for the maintenance of the mutual deterrent shield," and that since a world organization capable of maintaining the peace without a deterrent shield will not be formed in the foreseeable future, national forces will continue to be needed to maintain law and order. He envisions the need for smaller, lower-cost weapons systems, with an increasing role for the Navy in providing technical and economic assistance to underdeveloped nations.

"Opinions and Predictions of Weapon Requirements," Technical Lecture Series presentation, NOTS, Pasadena, 8 March 1963

The first six pages of this talk are a nearly word-for-word reiteration of the speech McLean gave in April 1957 (see "Personal Opinions on Weapon Requirements," the first speech in this section). In the second part of his 1963 talk McLean presents his updated projections of naval warfare needs, listing innovations the Station could pursue to meet these needs. He recommends that the Station consider broadening its scope of activities to include consideration of social and economic factors in the selection of best weapon approaches to pursue.

"NOTS Presentation," presentation at BuWeps R&D Planning Conference, 19-21 November 1963

This speech is a compilation of many of McLean's ideas on projects the Navy should undertake, both undersea and on the surface, in order to meet the challenges of limited war. He briefly describes studies with porpoises and birds that offer promise in the areas of target detection and classification, a sailing catamaran as a listening platform for both sonar and electromagnetic radiation, tactical weather modification, and "training aids and instruction methods which will allow us to express modern technology in terms which can be understood by indigenous groups." He concludes his speech by urging those present to invest in behavioral-sciences research to improve communication among the Navy organizations that need to work together on the weapons R&D process.

Speech on problem areas in limited warfare, presentation to Jason Division, IDA [Institute for Defense Analysis] Fall Meeting, Arlington, Virginia, 31 October 1964

McLean summarizes his views on limited warfare and gives a rationale for some of the unconventional programs (porpoise research, weather modification, etc.) NOTS pursued under his leadership.

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Presentation to the Underwater Ordnance Division, American Ordnance Association, Huntington-Sheraton Hotel, Pasadena, California, 10 Apr 57.

PERSONAL OPINIONS ON WEAPON REQUIREMENTS

by WM. B. McLEAN

I would like to discuss today my personal opinions on what new weapons developments are needed in the near future. I would like to make it very clear that these are personal opinions derived, it is true, as a result of my work for the Navy in the weapons development area, but they do not represent either the official opinion of the Navy or the final judgment of the Naval Ordnance Test Station. In fact, they will probably be stated in an extreme position in order to better arouse thought and discussion. I hope you will take them in this light and recognize that I intend to change them as more data becomes available.

I believe, first, that if our policy of a deterrent capability is successful, the next war will be primarily a naval activity. Short of an all-out nuclear operation, all of the areas of activity which we can visualize lie across a considerable expanse of ocean and our problem in maintaining any sort of military capability lies primarily in our ability to transport supplies and equipment across the ocean. That the Russians recognize this as being the critical item in any future conflict is well attested by the relative numbers of Russian naval craft. In the categories of submarines, mine layers, and high speed patrol craft, the Russian Navy exceeds our own by a factor of about five. These are the naval craft which can most easily deny us the ability to ship equipment overseas on the surface of the water. The problem of primary importance to us is how can we best equip ourselves for overseas transport.

We have heard a lot of discussion about the possibilities of doing this by air. I think any calculations will show that if the distance be traversed is as long as 3,000 miles, an airplane's capacity is about sufficent to supply its operations with the necessary fuel and that very little margin is left for other equipment. The surface ship also is in a peculiarly vulnerable position at the present time. During the last war it suffered considerable loss from the submarine even though the submarine could not proceed at a speed as great as that of the surface ship. With the present advances in nuclear propulsion and improvements in the underwater drag characteristics of submarines, it is perfectly possible for the submarine to exceed the surface ship in speed, detection range, and in the range of the striking power of its armament. The surface ship, being at the boundary of two media, is also subject to attack from the air. Here again it is highly deficient in speed, with not quite so black a picture with regards

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to deficiencies in detection range, and striking power of the armament. If we grant equal development efforts on surface capability, submarine capability and air to surface attack capability, the physical laws governing the operations of the weapons involved are such as to make the effectiveness of the surface ship very questionable. It is a good clear target for both air to surface missiles, and passive homing torpedoes. The same unfortunately, cannot be said for the characteristics of its two attackers as targets. The aircraft is rapidly becoming a smaller target for surface to air radars, and the submarine, by going to greater depths with more quiet propulsion, is becoming an almost impossible target for surface detection. It must be admitted that by giving fleet defense weapons high priority and anti-ship weapons low priority our surface fleet has some chance against our anti-ship weapons. I think that the same arguments which caused us to arrive at our relative priorities will have pushed the Russian tactics to the opposite extreme.

My conclusion is that if we wish to maintain overseas transport we must give serious attention to the development of methods of avoiding at least the air attack. This can be done by building submarines which are of about the same size of our present day tankers. Very little change of the design of these ships is needed to allow them to run completely below the surface since they are practically awash at present. The drag of a submerged body varies proportionately to the square of its dimensions, whereas the load carrying capability varies as the cube of the dimensions. We would therefore expect that bigger submarines will carry cargo at a lower cost per pound than small submarines. Structural weight can probably be reduced under that for surface ships since heavy storms can be avoided by running under them. A large fraction of the load which needs to be transported overseas can stand pressurization or immersion and it is only the living quarters of a submarines which need to be protected from the submerged pressures.

Having arrived at a position near the coast where we can expect to land, via the submerged route, we are now faced with the problem of contending with mine fields. The large number of Russian mine layers would indicate that these will present a very real problem in our future operations. It seems to me that this is the point at which air transport might be used effectively. If the submerged vessel is made up of a series of interlocking cargo compartments each of such a size that one can be lifted by a helicopter, these packages can be dropped in deep water off shore, marked by a radio beacon, and be available for pick up whenever possible by means of shore based helicopters. The package can be delivered directly to the point of use even though this may not be located directly on the shore. I believe that with proper design of containers, the efficiency achieved by reduction of number of loading operations would more than off-set the increased cost of the containers required. The submerged tanker, which probably will represent about 60% of the necessary transport, can be safely unloaded in the presence of mine fields by a plastic hose also carried to shore by means of a helicopter.

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Once having achieved adequate communications with overseas operations, our next problem is to carry out the necessary operations in a minimum of time. In this respect the proposed delivery of heavy supplies by helicopter will require a minimum of time loss in the construction of facilities, such as airfields and roads. Further, the development of individual helicopters, such as the flying platform, will allow the single foot soldier greater freedom of action. By his ability to move quickly the chance of a static stalemate can be reduced. This is important to us due to the probable high cost of overseas transport in the next war. The more quickly we achieve our objectives, the better.

Further, we need the capability of remote reconnaissance and control of weapons by means of television. At the present time, this seems to be both feasible technically and very desirable for the kind of quick actions we foresee in the future. If this is to be used extensively, it will require the development of a simple type of helicopter which might consist essentially of counter-rotating blades with jet propulsion at their tips. Such a blade system on one end of a bomb and a television camera on the other end would make a very effective ground control weapon since it can carry out reconnaissance at very low speeds and can be immediately ready for attack of any target which is detected. Other techniques for improving mobility and hence our ability to take and hold strategic points without the use of nuclear weapons also need critical study.

The above concentration on light weight conventional weapons is based on our ability to maintain a continuous long range deterrent threat. In order to do this we must have a capability for an attack with large nuclear weapons. This capability must have the highest possible degree of invulnerability. In my opinion the missile-armed submarine which can launch its missiles from a submerged condition represents the ultimate in this area, and I might add that in my opinion it is the easiest possible technical job of all those we are attempting. The reason it will be the ultimate in this kind of weapon is primarily because technically it is almost impossible to conceive of any technique which would simultaneously immobilize all of the submarines which might be at sea at any given time. All of our detection capabilities for deep running, nuclear powered, submarines have very short ranges and unfortunately the ocean covers 74% of the globe. In contrast to the threat posed by a missile base in Norway, which is very specific and at least for planning purposes can be knocked out with one well placed bomb, the submarine represents a threat from every point of the sea. Since the number of submarines at any position is unknown and unknowable, the degree of threat which is represented is a function of the psychological state of the enemy. The existence of the capability of launching missiles from any depth below the surface creates a threat which is capable of almost unlimited increase without the expenditure of funds for additional equipment.

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I sometimes wonder what our reaction would be if we found the ocean was strewn with electronic transponders which would give a very accurate simulation of a submarine target echo to add to those which already occur naturally from schools of fish and kelp.

By now I am sure that I have probably convinced you that I am working for the Navy, since I believe it is the Navy which has the best method of maintaining the deterrent capability necessary to prevent a nuclear war, and is also the group primarily responsible for carrying out any operations which will have to be conducted away from our shores if we are able to prevent the nuclear war. I will, however, avoid any endorsement of the suggestion to combine the Army with the Marines or abolish the Air Force and summarize by saying that I am convinced that however the responsibilities are divided we need:

1. Missiles to be launched from submerged submarines.

2. Nuclear powered, submarine transport.

3. Helicopters to carry supplies over mine fields.

4. Lightweight, inexpensive, individual air transport.

5. Hovering bombs using television cameras.

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Presentation made by Wm. B. McLean, Technical Director, during the visit of the Honorable James H. Wakelin, Assistant Secretary of the Navy for Research and Development, to the U. S. Naval Ordnance Test Station, China Lake, California, 2 October 1959

COMMENTS ON TRENDS IN WEAPON REQUIREMENTS

I should like to start our discussion of weapons programs by making a prediction of the possible course of future international events. Our weapons development should be designed to implement those parts of the prediction we like, and hinder those we don't like. Our predictions must change in order to keep current as our guesses about the relative strength of weapons and the possible course of national action change.

At the moment, we believe a nuclear stalemate has been sufficiently well established so as to cause Russia to lose more than she will win if she initiates any use of nuclear weapons. She will therefore continually press for any agreements which will inhibit our use of these weapons. I also believe it will take considerable provocation to induce the United States to start the use of nuclear weapons. Since Russia loses by any use of these weapons, she will take great care to limit her provocations to a level safely below the threshold at which we will be tempted to initiate their use. We can therefore expect a continuing series of international situations in which the United States will be faced with the choice of yielding to pressure, resisting with conventional weapons, or initiating the use of nuclear attack. We would like to assume that the United States will resist these pressures by the use of conventional weapons. We feel our job is to keep the Navy supplied with those weapons necessary for the provision of this resistance capability.

At the present time, we believe our national conventional weapon capability to be extremely weak due both to a lack of weapons suitable for use at the scene of activity, and to our inability to transport such weapons overseas. Since all of the immediately foreseen pressure points are located remote from our shores, we believe our problems to be doubly difficult.

In order to improve our capability to carry out naval activities at the scene of action, we need to improve our capability in four different areas in addition to the weapons which we have in production.

(1) We need weapons for air-to-ground attack which are capable of being released from our existing aircraft. These weapons are needed to destroy tanks, troops, and supplies. (For this purpose, the Bureau of Ordnance has initiated a program at the Station for the study of free fall weapons.)

(2) We need to provide the Marines with a weapon for close support. (We now have in process feasibility studies which will result in working models and development proposals for glide missiles to be launched from aircraft and controlled from the ground.)

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(3) The possibility of limited action in an area adjacent to friendly troops requires the Navy to develop the capability of dispensing non-lethal, chemical, and bacteriological weapons for the purpose of police-type action. (This is a capability closely related to the weapons for air-to-ground attack.)

(4) Quick action by the Marines is essential for limiting the spread of conflict. In addition to the vertical envelopment concept, we believe the Marines need a rocket-propelled, single man, expendable transport. (This concept is now in the thinking and possibility testing stage and involves technical choices between rocket-propelled, helicopter rocket-propelled, flying kites, etc.)

The problem of overseas transport requires immediate attention due to the known large number of Soviet submarines and to the fact that they are supplying these submarines to other nations. It seems entirely possible that a very small nation, such as Egypt, might sink our aircraft carriers by submarine action without causing us to respond with nuclear weapons. It is urgent that we protect our surface shipping to the best of our ability. For this purpose, we have proposed the two-man torpedo called MORAY. This is designed to be used by surface ships which will be forced to proceed independently in order to minimize the problems of defense against air attack. The proposal for this weapon will be described later in the program.

Our interpretation of the laws of nature allows us to postulate, at best, a continuously diminishing capability for the protection of the surface ship. The crucial element in the duel between the surface ship and aircraft, and between the surface ship and submarine, is the relative detectability of each craft for the other. It can be foreseen that the surface ship will always represent a better target for the aircraft and submarine than does either of these targets for the surface ship. Our present state of technology will allow us to shoot weapons from any of these platforms to the maximum range made available by their detection capability. Since the surface ship will shortly be less maneuverable and slower than either of its adversaries, the picture for its survival is not encouraging. We would not recommend immediate abandonment of this vessel. However, we do recommend that everything possible be done through research to hasten the replacement of the importance of the surface ship in maintaining our overseas life lines.

The first step in this direction should be the establishment of submarine transport for oil, supplemented by the airborne transport of supplies not immediately adaptable to sub-surface transport. We can expect that future developments will result in an ever higher concentration of ships capable of submerged travel to carry out the mission of the Navy. We thus expect that naval warfare will occur at an increasing rate below the surface, rather than on the surface of the sea. For this reason, oceanography and an understanding of the characteristics of

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travel and operations in the deep ocean become increasingly more important. Because of this, we have just established a group working on oceanography to bring us up-to-date with the work going on in this field at other laboratories, and to give us the opportunity to plan those experiments which will put us in the best position to advance the Navy's interest in undersea weapons and warfare. We can expect that the work will, at first, follow the lines of pure research and become more applied as new ideas are developed. We will discuss our plans for initiating this program in more detail later today.

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U. S. NAVAL ORDNANCE TEST STATION
China Lake, California

SENIOR PERSONNEL CONFERENCE

Presentation by WM. B. McLEAN, Technical Director

China Lake, 29 January 1960
Pasadena, 8 February 1960

Captain Hollister has described for you the fact that the Naval Ordnance Test Station has a unique position to occupy in the development of weapons for limited warfare. I would like to outline some possible techniques by which warfare can be kept limited; what limits the choice of weapons necessary to carry out such an operation; and, how we can best plan our program so that the United States will have the capability of deterring limited aggressions as well as the capability of preventing all-out nuclear attack.

The problem of defining what keeps a war limited is so difficult that most of the people planning military programs throughout the country tend to shy away from this kind of decision completely. The Weapons Planning Group of this Station has been investigating the characteristics of limited warfare and have found it a very difficult area in which to achieve agreement as to the important factors. I find it equally difficult. In order to stimulate thought, therefore, rather than because I believe I have any unique solution, I would like to state some of the things which seem to me to have arisen out of the discussions of the past year.

First, a war will be kept limited only if the apparent gains and losses for both sides are kept relatively small. Both sides need to be continuously in a position where they can terminate hostilities without suffering a serious loss of either property or prestige. Second, people have demonstrated over a large period of time that they will die for a cause provided they are sufficiently convinced that their cause is just and right. In the age of nuclear weapons, this dying could be equivalent to the decision to use all-out nuclear warfare. If warfare is to be limited, it is therefore essential that the right and wrongness of any action be kept confused. We need to learn to operate in an indefinite and changing atmosphere. The Soviet Union has shown considerable skill in accomplishing this confusion with respect to the motives of the United States. We need to recognize this and learn how to employ the same weapon in reverse. A third technique for keeping warfare limited is to fight by proxy. This will be an effective system until all nations are able to achieve sufficiently large nuclear stockpiles. I am sure you can all think of other techniques for limiting warfare. Our wild west shows provide us with lots of raw material which involves the emotional

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responses pertinent to the transition from individual sovereignty to group rule which seems to have its parallels now on a national and international scale. Our studies should help to shed light on more methods.

The variety of weapons for limited warfare seems to be almost without limit. However, they must have some general characteristics in common.

First, they must be low in cost since warfare can be expected to remain limited only so long as the gains and losses for each side are not large. If the cost of limitedwarfare becomes excessive, it will probably be terminated by compromise.

Second, the weapons must be producible in large number. The last two major conflicts using conventional explosive weapons were won primarily due to the high productive capability of the United States industry. The operations in Korea were brought to a standstill by the same means. It would appear that in any future limited engagements we will need to depend on our capability for high production in order to offset our potential enemies' super-abundance of manpower.

Third, our weapons should require a minimum of training for their effective use. Wherever possible in limited engagements we would like to supply weapons rather than manpower. This puts a severe limit on the time available for training people in the use of these weapons.

Our potential adversaries recognize clearly that limited warfare is continuous with other methods of exerting influence, such as scientific competition, economic competition, competition for the exploration of the world's undiscovered resources, and missionary activities in underdeveloped countries. The importance of the latter two have almost been forgotten by us. All of these activities have in the past played dominate roles in the struggle of various nations for positions of power and influence. If we believe that a position of stable nuclear deterrence can be achieved, it is reasonable to expect that the same operations will become important in the future. In the past, all of these operations have been dependent upon the control of the seas. In the future, as in the past, I believe that the nation which can best use the oceans as a highway will continue to exert its influence over the widest area of the world. Technology has, however, brought about two significant changes in the importance of sea communications. First, the air now provides a more rapid means of communication between countries. However, its use can be limited and controlled in times of war by the use of ground-launched guided missiles. Second, the surface of the ocean has now lost much of its old characteristics of freedom of motion due to the activities of both aircraft and submarines. If it were not for the advent of nuclear power, freedom of motion across the oceans could now be denied to the ships of any country by a very low expenditure of effort by another country wishing to establish a blockade. With nuclear power, however, the volume of the ocean is now open to uninhibited travel and, because of the highly concealing characteristics of

seawater, we would predict that it will remain open for a considerable period of time to come.

With this background then, we can see the technical work of the Station shaping up in three different areas: immediate, long-range, and distant future. Our immediate jobs are quite clear. We need to complete and put into service use those weapons systems for the delivery of bombs, rockets, and inexpensive guided missiles which have been developed since the end of World War II. These systems employing controlled fragmentation clusters, improved air-to-ground fire control systems, and simplified guidance techniques will allow tremendous improvements in air-to-ground effectiveness over those which were available in Korea. The psychological effects of these weapons are fully as important as the physical damage which they can create. I recently served on a Department of Defense committee studying air-to-ground weapons. It seemed to me significant that all of those organizations which were subjected to air-to-ground attack felt that their operations were severely hampered unless they were able to maintain air superiority. Air superiority is considered essential by both the Marines and the Army. On the other hand, those organizations concerned with supplying air support, the Air Force and the Bureau of Aeronautics, believed that air-to-ground weapons are decidedly ineffective due to the inability to locate and hit targets from the air. If both of these evaluations are taken at face value, and I personally believe they are reasonable, the conclusion would be that the prime effect of air-to-ground weapons is to prevent the troops on the ground from carrying out their missions through fear of attack from the air. Anything which will increase this fear, therefore, will be an effective weapon.

The next area of activity which we need to undertake is of a somewhat longer range nature and consists in demonstrating the technical competence of the United States through an exploration of the unknown. This has long been an assignment of the Navy in peacetime, and its importance today is increased by the fact that such a large percentage of the research and development effort of the country is financed through military appropriations. The two major unknowns at the present time are space, and the volume and floor of the ocean. Russia has demonstrated an interest in both of these areas of exploration. Our work should be planned so as to achieve exploratory firsts. Russia has put the first satellite into orbit and has taken the first picture of the back side of the moon. The Navy Electronics Laboratory has accomplished the remarkable feat of being the first to reach the bottom of the ocean. I am sure that there are a limitless number of firsts yet available for the Station to accomplish if we have the courage and skill to look for them. We can still put a satellite into orbit without guidance. We could be the first to have a remotely controlled telescope in orbit. We could be the first to take underwater pictures of Soviet submarines patrolling off our coast. We could be the first to measure accurately the drag of a live sea animal. These are a few of the "firsts" we are now considering. I am sure that any of you with

imagination can continue to expand such a list until it will demonstrate to the world that we have a technical capability second to none. In the world today, people will group around those organizations and countries which can demonstrate such leadership.

In the past, the expansion of national influence by the use of missionaries has been well demonstrated. The most successful of such missionaries have been those who could provide proved technology leading to a better way of life. In a cold, limited war, the missionaries correspond to the foot soldiers of the hot, limited war. They are needed to follow and consolidate the ground taken over by our demonstrations of technical competence. Russia has, and is exploiting, such a technical missionary force and is rapidly training a large number of people in the technologies necessary to assist underdeveloped countries. In the past, such peaceful operations have been clearly distinguished from military operations. However, in the more distant future, as wars become more and more limited, and industrial competition more aggressive, who knows but what the Navy may verywell find itself in the position of being unable to distinguish between military and industrial operations. Since the military organizations now are expending the bulk of the country's money for research and development, we may well find that these organizations, and particularly the Navy, must assume the responsibility for providing, supplying, and protecting the technical manpower who will be needed to assist the backward countries whom we would like to have on our side. I believe that the people who have been protecting national prestige through the development of military equipment can shift quite naturally to achieving this same objective on a broader and less destructive basis through the exploitation of technical knowledge and capabilities.

Presentation to the American Ordnance Association Fuze Section, U. S. Naval Ordnance Test Station, China Lake, California, 24 May 1960, given by Wm. B. McLean, Technical Director in accepting the AOA Blandy Medal.

Members of the American Ordnance Association, and especially the members of the Fuze Section, I appreciate greatly the honor you have conferred on me and the opportunity to speak to you tonight.

Nineteen years ago this coming summer, I had my first introduction to the problems of designing military equipment. I joined the Department of Terrestrial Magnetism to work on a new secret device known as the proximity fuze. Later, I moved to the Bureau of Standards to work on the non-rotating version of this device. I believe this early experience in the design of fuzes was the most valuable training which I have ever received.

It is unfortunate that every designer of military equipment cannot at some time be exposed to the problems of designing fuzes and their arming mechanisms. This kind of work requires the most rigorous attention imaginable to a multitude of simultaneous design requirements. A fuze must be designed with a minimum number of parts, with each part doing a multitude of functions. Its reliability needs to be above the 90% mark, and its probability of failure in an unsafe manner should be vanishingly small. Many hours of effort at the design board and in testing must be spent trying to design the various pieces in such a manner that it is humanly impossible to assemble them in an unsafe position.

I learned an unforgettable lesson about the difficulty of designing military equipment when I visited the assembly line for one of our new fuzes. One part in this design included a boss on a rotor which was carefully located so as to prevent the insertion of the part in the armed position. On the production line, this part appeared to be superfluous and sometimes in the way. It was, therefore, being carefully removed by filing as one step in the production procedure. I have never again been tempted to believe that a product can be produced by means of drawings alone.

In the design of fuzes, we used to spend considerable time working through various modifications before reaching the prototype state. The final product which resulted was usually so simple in appearance that no one could understand how it took so long to complete it. This tends to make the design of fuze mechanisms a relatively thankless job. The degree of appreciation forthcoming for the completion of a really clever fuze mechanism which is safe, reliable, and easily producible is not really worth the many hours of careful design, rigorous testing, and general difficulty which is involved. This is probably the reason why many fuze designers leave the business at an early age and get into something that is easier and more rewarding, such as the design of guided missiles, fire control equipment, or long-range search and detection systems. Here,

most of the problems can be solved in a relatively straightforward manner by simply adding more components and by increasing the price. People hold in great awe anyone who can understand the multitude of components and precision hardware which goes into one of our modern missile systems. The rewards for this type of design in terms of prestige and appreciation in our society are tremendous. Americans seem to enjoy complicated designs. A complicated car will sell better than a simple one which is functional in design. We are beginning to have some vague worries about the increasing costs of these complicated systems, but these worries have not yet become sufficiently strong to make us stop buying them either in our commercial products or in our military equipment.

I would like to predict tonight that our national survival in the future may very well depend on a re-awakening of an appreciation of the kind of simple design represented by the 20 milimeter gun fuze to replace the complication of our existing missile systems. This change in design taste would be analogous to the change in architecture from the gingerbread of the 1850's to the aluminum and glass of today. We need this change in order to survive.

I believe that we all have the feeling that all-out war has been established as being highly undesirable and of very little profit to any of its participants. We also believe that the Utopia of the cessation of all human conflict will not be achieved in the immediate future. At the present time we hear a great deal of talk about the problems of fighting a limited war. This is the type of warfare in which the national survival of a nation armed with nuclear weapons is not threatened. It is a type of warfare which is carefully calculated with respect to gains and losses on an economic and manpower basis. We need to be prepared to move fast and to attack with the right kind of weapons. These weapons should be of minimum complexity in order to accomplish our purposes. When I watch the Marines unloading the equipment required to set up a TERRIER field station, I cannot help but wonder how this work would progress if it were taking place in a jungle and was opposed by soldiers equipped with some relatively simple but effective weapon, such as a blow gun.

We have not clearly delimited any specific types of operations which will be carried out with non-nuclear weapons systems. The number of choices among such weapons is almost unlimited and we, therefore, find it very difficult to get the development started in any specific system. None of these systems will be perfect and none of them will fit all possible situations. These weapons will, however, have some general characteristics in common.

FIRST, they must be low in cost since warfare can be expected to remain limited only so long as the gains and losses for each side are not large. If the cost of a limited operation becomes excessive for the economy of a country, the action will probably expand by the use of nuclear weapons, or it will be terminated by compromise.

SECOND, the weapons must be producible in large number. The last two major conflicts using conventional explosive weapons were won primarily due to the high productive capability of United States industry. It would appear that in any future limited engagement we will need to depend on our capability for high production in order to offset our potential enemies' super-abundance of manpower.

THIRD, our weapons should require a minimum of training for effective employment. Whenever possible in limited engagements, we would like to supply weapons rather than manpower. In order to do this quickly we will have a severe limit on the time available to train people in the use of our weapons.

These types of requirements are not easy to meet. They require very careful design, extensive testing during the prototype stages, and extensive feedback between test, production, design, and conception. I do not believe it is possible to achieve the kinds of weapons we will need in limited warfare by writing down specifications and then designing to meet these specifications. This provides no mechanism for taking account of improvements which result from experience obtained by using weapons in the field. Improvements based on practical experience can well mean the difference between success or failure in an evenly balanced operation.

We all know that we need clever and imaginative designs in order to have the most successful new weapons. We have tried reaching this objective by committee, by specification, and by operational research. It is my belief that none of these techniques will lead to the product which we desire. The design of successful equipment seems to me to be much more of an art than it is a science. The science provides the tools by which the design is carried out but, as we get more science the number of technical alternatives which are available to any equipment designer increases rather than decreses. His choice, among the infinitude of various alternatives available, requires creative and artistic talent which is similar to those required in any other form of art. If we are to have a truly integrated design, a single man must understand what he is trying to create, must be responsible for the choices, and must weave the various elements of the design into the integrated system. After a design is completed, a committee of skilled critics will be useful in its evaluation. But to have a committee operation try to specify a new weapons system will generally lead to a design which has all the finished beauty which one would expect of a painting which was the composite work of a group of art critics.

I believe if the United States is to be successful in either its military or economic competition, we will in the future need to learn to appreciate and to foster creative design capabilities. We have been successful in doing this in other forms of artistic endeavor, and I do not believe the requirements are any different in this particular field of art. A skilled artist is usually judged on the basis of his work. He is born with a certain native skill which improves and develops through practice and experience. If we want a new mural for a public building, we pick an artist of recognized competence, give him

some general ideas of what is desired, and then leave the creative work to his good judgment and demonstrated skill. Up to the present, we have not been able to provide this same type of artistic freedom for our designers of technical equipment. Our normal practice in this area is to get together a committee of experts, go over the problems in detail, arrive at a series of detailed specifications, and then give the responsibility for the carrying out of the design to the corporation which is the lowest bidder. I expect that our military equipment will reflict this process and will continue to be a conglomeration of expensive gingerbread until such time as we learn to recognize and appreciate creative design ability and learn to give the people with recognized capability the tools and freedom to carry their ideas through to completion. After a design has been demonstrated, we can use committees of critics effectively. Then, we can turn the technical critics loose and decide which of the hopeful masterpieces are the ones which we really want to buy. This may take extra time for the accomplishment of the final product, but I am sure that the improvement in the product will be well worth waiting for.

Fuze designers as a group are most aware of the need for artistic systems. It is in this area that the art of design has paid off with great dividends. Therefore, I hope you will not think of me only as a frustrated designer if I plead with you tonight to find some way to rescue the design of our military equipment from the morass of integration, coordination, centralization, and detailed specifications in which a present it is sinking. Let's find a way to first create new designs and then try to judge them. I do not believe the reverse order will work.

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(Presentation to NOTS Advisory Board, November 1962)

UNCLASSIFIED

LONG RANGE RESEARCH AND DEVELOPMENT GOALS FOR NOTS

by

WM. B. McLEAN
Technical Director

At the last meeting of the Advisory Board, we discussed the absence of believable long range objectives for the Navy which could serve as a framework into which we might fit the Station's objectives. It was suggested by the Advisory Board that such objectives could well be stimulated if the Station were to make a start on such planning.

In response to this suggestion, we see the establishment of long range goals for the Naval Ordnance Test Station to require three essential steps for its accomplishment. The first step is to form a picture of the kind of military organization which the Navy should be in the future in order to carry out the functions which we can guess will be required of it. The second step is to evaluate the kinds of research needed to change our national capabilities from those which exist today to those we desire in the future. The third step is to decide which of these areas of research or development are particularly suitable for prosecution by the organization and facilities existing at the Naval Ordnance Test Station.

This will require an understanding of both our own capabilities and those of other Navy and military organizations throughout the country. If an area of research is needed for which no organization now has the capability, then careful evaluation will be required as to whether our facilities, or those of some other organization, are best adapted to the modification needed to carry out the new work.

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I ESTABLISHMENT OF A LONG RANGE PICTURE OF FUTURE NAVY CAPABILITIES

The function of the Navy of the future should be to support the United States objective of winning in an international competition. This may not mean merely the smashing of Communism to the exclusion of all other possible threats. If we believe strongly in the American way of operating, then we should expect that the Soviet Union and China might be far greater threats if they were non-Communists than if they are Communists. In order to define "win" for the United States, we need to consider what we want for us, what we want for the neutrals, and what we want for the Communists. For us, we would of course like security, both economic and military. We would also like an increase in affluence, autonomy, and freedom for the individual and the group. We would like to see the neutrals have security from both an economic and military standpoint, to have freedom in the exercise of their capabilities, and to increase their general effectiveness and affluence. It would be nice if they could achieve these things under our assistance and guidance so that we could increase the effectiveness of our leadership.

Our primary goal with respect to the Communists is to change their goal of world domination, and particularly the means which they plan to use in the achievement of this goal. We would like to decrease the likelihood of their using violent subversion, or violence in other forms. If we can convert the battleground between us to one that is primarily economic and political, and we have confidence in our way of doing things, then we should really consider ourselves successful.

Military power has historically been one of the tools by which nations exert influence over other nations. The effect of this influence has varied from the purely deterrent function to the objective of smashing the army of the enemy, to occupying enemy territory, or, as in World War I and II, to eradicating the productive capacity of the enemy. In general, all of these activities involve the destruction of personnel. The philosophy of destroying people reached its culmination after World War II, and this was the first time that the complete immorality of warfare was accepted. Our objectives became expressed by such phrases as, "A Bigger Bang for the Buck," and, "Warfare has no rules." Since modern warfare is so much a matter of the construction of weapons, no part of the population is free from the engagement in military operations under the conditions of modern warfare. We still cling to some shred of humanity in warfare by discussing the possibility of very accurate missiles to fire at military installations in order to spare the general population. This would have some semblance of nobility except for the technical fact that the warheads planned to knock out hardened military targets require yields which are at least ten times greater than the yields required to kill all of the people in the surrounding areas. Therefore, whether we attack purely military targets, or whether we attack the total population with nuclear weapons is immaterial. In either case, we now have the capability of very rapid destruction of total populations. Further, the time necessary for such destruction can easily be made much shorter than the time necessary for the people involved to consider the desirability, or lack of desirability, of capitulation in the presence of enemy pressure.

The fact that we have achieved the possibility of nearly total instantaneous destruction requires a reconsideration of the basic tenets of military operation. The establishment of the rules of conduct for military operations in the future can be expected to be heavily influenced by the nature of scientific progress. It would therefore seem that a technical organization, such as NOTS, may be in a desirable position in which to make some informed guesses as to what these rules of conduct for military operations might become. This type of broad guess can then form a basis for a discussion with the people who have the responsibility for formulating national policy. By such a process of discussion, we may be able to generate the guidelines which we need for planning our future research.

For the purposes of initiating the discussion process, I would like to make the following assumptions:

(1) An invulnerable delayed response deterrent system will be established between two or more major powers. This will prevent the all-out use of force by allowing time for rational responses in the settlement of international difficulties.

(2) A mutual agreement on the abolition of all techniques for mass destruction, such as nuclear weapons, or lethal biological weapons, will be accomplished for all limited warfare purposes. These weapons will exist only for the maintenance of the mutual deterrent shield.

(3) A world organization, capable of maintaining law and order without a deterrent shield, will not be established in the next 25 years. National forces to perform international control functions will be a continuing requirement during this period.

I would expect that the discussion of the validity or lack of validity of this type of assumption can last for any length of time and will only result in general confusion. Such assumptions seem to me, however, to be a realistic requirement for the continued survival of civilization. I would also like to assume that the survival of civilization will be a reasonable and perhaps almost necessary starting point for the purpose of generating long range planning.

In the type of picture presented under the above assumptions, the Navy has a continuing function with respect to providing the invulnerable deterrent system which will make instantaneous response unnecessary. This is a system which we have helped establish and which will require continuing clean-up work. I do not believe it will require a major continuing investment of the research and development capacity of the Naval Ordnance Test Station.

I expect that in the coming years the Navy will continue to have the requirement of carrying out the kind of activity for which the Marine Corps was established; this is, the application of pressure at potential trouble spots prior to the possible opening of large-scale hostilities. The modern limited warfare concept is very close to the traditional Navy role. In order to perform this function we will have to increase our mobility and decrease the vulnerability of our forces to interception during their transit to the target area. One technique for cutting down the vulnerability would be the creation of a relatively large, expeditionary-type submarine which would carry all of the forces necessary for making and

establishing landings in undefended areas. Perhaps a better solution to this problem might be accomplished with a smaller amount of development of new equipment by assigning to the Navy and the Marines the job of assisting underdeveloped nations on a continuing basis. They could apply the advanced U. S. technology in order to create better economic and average living standards. This would require the development of equipment particularly suited for specific countries. We must recognize the fact that revolutions will occur if wide separations in standards of living exist in any country. We will need development of improved techniques for assisting people to understand technical operations. If such equipment can be used by the Marines, supported by the Navy, in improving living conditions in a country, they can at the same time learn a great deal about political and other operations within the country which will either prevent the occurrence of future troubles, or lead to the effective control of troubles if they occur.

The Navy of the future will need to continue to operate under, on, and over the sea. It will need to pay considerably more attention to the relationships between kill probability of a weapon and the number of units involved in the engagement. The Lanchester duel formula states that the kill probability of a weapon, multiplied by the square of the number of weapons involved, will be a constant if the two forces are evenly matched. As long as weapons have kill probabilities of one in a thousand, or less, it can be reasonably foreseen that improvements in weapon kill probability can be used to offset considerable numerical superiority of the enemy.

The perfection of guided missiles has raised weapon kill probabilities against most targets into the range of between one-tenth and one-half. It seems highly probable that weapons with this degree of kill probability can be develcped for all targets which can be detected and classified. It would, therefore, appear that the future Navy will have to concentrate much more heavily on achieving large numbers of weapons and weapon systems than they will on the achievement of higher effectiveness of single weapons. This means that future emphasis must be on smaller systems, and systems with less requirements for manpower and with lower production costs. A Navy consisting of more units involving lower capital investment can be achieved. We will simultaneously improve our ability to risk these units without sustaining a loss of sufficient magnitude to involve the risk of increasing the level of conflict. This will be important in handling situations such as Cuba.

Another function of the Navy of the future will be to provide the overseas transport necessary to support the Army and the Air Force in their operations in remote locations. The current Howze Board report proposes an Army in which trucks, jeeps, mobile guns, tanks, and other forms of ground transportation are to be replaced by various means of air transport. This will greatly increase the effectiveness of the Army with respect to mobility, yet at the same time decrease the weight of material which must be transported as fixed hardware, and materially increase the requirements for oil, fuel, and lubricants. At the present time, between 40-50% of the material needed by the Army is petroleum, oil, and lubricants. If the Howze Board report is implemented, this ratio should increase significantly. At a 3,000 mile range, Air Force transport plans carry

about one-half fuel and one-half payload. It can therefore be foreseen that the future role of the Navy in supporting the Army and Air Force at ranges of over 3,000 miles will primarily involve the supply of petroleum, oil, and lubricants.

II SPECIFIC DEVELOPMENTS NEEDED TO ENABLE THE NAVY TO MEET ITS FUTURE FUNCTIONS

The Navy will need a high concentration on the reduction in the cost of all of its systems in order to increase the numbers which it will have available. The Navy needs to improve its capabilities to provide training, support, and motivations for governments in underdeveloped countries. The Navy needs to develop techniques for the undersea transport of first, petroleum, oil, and lubricants, and second, other supplies which can be packaged for undersea storage. Such undersea transport will free the Navy from the tremendous problem of protecting its convoys from air attack, and thus allow it to generate the large numbers of other vessels which it will need for the effective accomplishment of its mission.

Active radar and sonar have signals for detection which fall off as the fourth power of the range, whereas the signal generated to disclose their position only falls as the square of the range. The force which makes the most effective use of passive detection will therefore have a clear advantage in a duel with a force dependent on active detection. The Navy needs urgently both passive sonar and passive electromagnetic radiation detectors which will listen continuously at all useable frequencies and will plot the direction of arrival of all signals. In the compromises which must

be adjusted, the ability to detect all frequencies quickly is more important than long detection ranges. Such passive detectors can also locate objects which may be illuminated from independent sources and still maintain the advantages of passive range in a duel.

The Navy's present techniques for over-the-beach landings are very vulnerable to inexpensive shore-launched antiship missiles. An expeditionary submarine probably can find an unprotected section of an enemy shoreline to achieve a landing under limited warfare conditions, particularly before the resistance is well organized. It is hard to believe that a large convoy of landing craft can be equally successful in achieving surprise, particularly in view of the need for radio communications in organizing the operation. The Navy and the Marines will need practical means of transport from a submarine to some area beyond the shoreline. This could include underwater swimmers, surface craft, or light aircraft and helicopters.

In most of the potential trouble spots of the world, the only rapid means of transport will be by air. Air delivery of weapons will continue to be a prime means of attack against targets on the ground. In fact, it will probably replace much of the present field artillery. Close air support of ground troops will continue to be important. This operation is characterized by the fact that the location of targets is known by the troops on the ground, but is difficult to convey to the aircraft delivering armament. The problem might be eased through the use of slow missiles designed for air delivery, but ground controlled.

The Navy will need a minimum cost ship which can be produced in very large numbers in order to apply pressure with a minimum penalty in case of loss.

To summarize the specific developments needed by the Navy, we can enumerate the following:

(1) Training devices to indoctrinate its own people in the use of advanced equipment, and similar devices to explain modern technology to uneducated personnel in underdeveloped countries.

(2) The undersea transport of fuel, oil, and lubricants, and such other supplies as can be packaged for underseas storage.

(3) Improved passive detection devices for electromagnetic radiation and sonar signals which will allow continuous monitoring of all useable frequencies.

(4) The development of a ship which can perform useful military functions and at the same time be constructed in the numbers and at a cost approximately that of the Chinese junk, the PT boat, or the Russian trawler.

(5) Develop improved passive direction-finding equipment to be used with external illuminating equipment.

(6) Improved techniques for over-the-beach landing.

(7) Air delivery of weapons to the firing line.

(8) Control of air-delivered weapons by troops on the ground.

III SPECIFIC AREAS WHERE NOTS IS FITTED BY INTEREST, MANPOWER, AND FACILITIES TO CONTRIBUTE TO THE NAVY'S FUTURE REQUIREMENTS.

In looking over the above list of items which the Navy will require in the future, it becomes apparent that the major prime developments have not been our specific responsibilities. The one area in which we have had considerable past experience, and one where we should continue to excel, is in the development of weapons to attack various kinds of targets using air

delivery. Such weapons should include (1) continued improvement of air-to-air missiles, and (2) development of a series of air-to-ground missiles to attack targets of varying hardness using both fixed-wing aircraft and helicopters. If targets can be located visually, homing using contrast tracking with narrow field of view seems applicable in missiles of various sizes. If the target can be located by means of its electromagnetic radiation, then cruise missiles and rotating wing devices offer the possibility of effective homing. Missiles for air delivery and air launch, but with command control from the ground, would appear to be both desirable and easy to construct.

The Station has a relatively meager effort in the behavioral sciences including the investigation of improved techniques for training and teaching. If the Navy's mission can be broadened to include economic and technical assistance to underdeveloped countries, then I believe that the behavioral science work should be expanded to include the complex problem of fitting a modern technological development to social groups ranging from the stone age to the early feudal system.

The problem of developing a minimum cost ship is intimately related to the kinds of detection equipment and weapon systems which can be evolved. I believe that NOTS capability in both underwater weapons and air weapons, together with its capability on computers, radar, and sonar, would make it possible for us to do an integrated design of such a ship, together with its weapons systems and fire control equipment. The problems of low cost and high construction rates, together with maximum weapon effectiveness of such

a ship, constitute such a difficult problem that I believe the Navy could well afford several approaches to the solution of the problem before any ship is put into large scale production. It would seem that modern technology might be able to build an improvement over the Chinese junk or the Seviet trawler to be competitive on a numbers basis in carrying out the various Navy missions, ASW, patrol, troop landings, etc. This is the type of project where I believe that NOTS should be willing to undertake a ten percent program of the type I have proposed for competitive purposes directed toward novel solutions of the problem. Such an integrated system could focus our various developments toward the achievement of a worthwhile total objective.

In addition to the above, the goals for the individual departments are also submitted as enclosure (1).

Enclosure
NOTS Conf TS/63-86, NOTS Plans and Goals for FY 1963

(Technical Lecture Series Presentation, NOTS, Pasadena, 8 March 1963)

OPINIONS AND PREDICTIONS OF WEAPON REQUIREMENTS

by

WM. B. McLEAN
Technical Director

I have been accused of making my proposals too soon before the ground work has been built up. I would like to try an experiment today and give a speech which now lacks one month of being six years old to see if it is more acceptable than it was then. It might help in considering the question of whether we can predict five years in advance.

(Ref. 1) I will discuss today my personal opinions on what new weapons developments are needed in the near future. (The near future was obviously optimistic.) I want to make it very clear that these are my personal opinions derived, it is true, as a result of my work for the Navy in the weapons development area, but they do not represent either the official opinion of the Navy, or the final judgment of the Naval Ordnance Test Station. In fact, they will probably be stated in an extreme position in order to better arouse thought and discussion. I hope you will take them in this light and recognize that I intend to change them as more data becomes available.

I believe, first, that if our policy of a deterrent capability is successful, the next war will be primarily a naval activity. Short of an all-out nuclear operation, all of the areas of activity which we can visualize lie across a considerable expanse of ocean and our problem in maintaining any sort of military capability lies primarily in our ability to transport supplies and equipment across the ocean. That the USSR

recognizes this as being the critical item in any future conflict is well attested by the relative numbers of Soviet naval craft. In the categories of submarines, mine layers, and high speed patrol craft, the Russian Navy exceeds our own by a factor of about five. These are the naval craft which can most easily deny us the ability to ship equipment overseas on the surface of the water. The problem of primary importance to us is how can we best equip ourselves for overseas transport.

We have heard a lot of discussion about the possibilities of doing this by air. I think any calculations will show that if the distance to be traversed is as long as 3,000 miles, an airplane's capacity is about sufficient to supply its operations with the necessary fuel and that very little margin is left for other equipment. The surface ship also is in a peculiarly vulnerable position at the present time. During the last war it suffered considerable loss from the submarine even though the submarine could not proceed at a speed as great as that of the surface ship. With the present advances in nuclear propulsion and improvements in the underwater drag characteristics of submarines, it is perfectly possible for the submarine to exceed the surface ship in speed, detection range, and in the range of the striking power of its armament. The surface ship, being at the boundary of two media, is also subject to attack from the air. Here again it is highly deficient in speed, with not quite so black a picture with regards to deficiencies in detection range, and striking power of the armament. If we grant equal development efforts on surface capability, submarine capability and air-to-surface attack capability, the physical laws governing the operations of the weapons involved are such as to make

the effectiveness of the surface ship very questionable. It is a good clear target for both air-to-surface missiles, and passive homing torpedoes. The same, unfortunately, cannot be said for the characteristics of its two attackers as targets. The aircraft is rapidly becoming a smaller target for surface-to-air radars, and the submarine, by going to greater depths with more quiet propulsion, is becoming an almost impossible target for surface detection. It must be admitted that by giving fleet defense weapons high priority and antiship weapons low priority our surface fleet has some chance against our antiship weapons. I think that the same arguments which caused us to arrive at our relative priorities will have pushed the Soviet tactics to the opposite extreme.

My conclusion is that if we wish to maintain overseas transport we must give serious attention to the development of methods of avoiding at least the air attack. This can be done by building submarines which are of about the same size as our present day tankers. Very little change of the design of these ships is needed to allow them to run completely below the surface since they are practically awash at present. The drag of a submerged body varies proportionately to the square of its dimensions, whereas the load carrying capability varies as the cube of the dimensions. We would therefore expect that bigger submarines will carry cargo at a lower cost per pound than small submarines. Structural weight can probably be reduced under that for surface ships since heavy storms can be avoided by running under them. A large fraction of the load which needs to be transported overseas can stand pressurization or immersion and it is only the living quarters of a submarine which need to be protected from the submerged pressures.

Having arrived at a position near the coast where we expect to land, via the submerged route, we are now faced with the problem of contending with mine fields. The large number of Soviet mine layers would indicate that these will present a very real problem in our future operations. It seems to me that this is the point at which air transport might be used effectively. If the submerged vessel is made up of a series of interlocking cargo compartments each of such a size that one can be lifted by a helicopter, these packages can be dropped in deep water off shore, marked by a radio beacon, and be available for pick up whenever needed by means of shore based helicopters. The package can be delivered directly to the point of use even though this may not be located directly on the shore. I believe that with proper design of containers, the efficiency achieved by reduction of number of loading operations would more than off-set the increased cost of the containers required. The submerged tanker, which probably will represent about 60% of the necessary transport, can be safely unloaded in the presence of mine fields by a plastic hose also carried to shore by means of a helicopter.

Once having achieved adequate communications with overseas operations, our next problem is to carry out the necessary operations in a minimum of time. In this respect the proposed delivery of heavy supplies by helicopter will require a minimum of time loss in the construction of facilities, such as airfields and roads. Further, the development of individual helicopters, such as the flying platform, will allow the single foot soldier greater freedom of action. By his ability to move quickly, the chance of a static stalemate can be reduced. This is important to us due to the probable high cost of overseas transport in the next war. The more quickly we achieve our objectives, the better.

Further, we need the capability of remote reconnaissance and control of weapons by means of television. At the present time, this seems to be both feasible technically and very desirable for the kind of actions we foresee in the future. If this is to be used extensively, it will require the development of a simple type of helicopter which might consist essentially of counter-rotating blades with jet propulsion at their tips. Such a blade system on one end of a bomb and a television camera on the other end would make a very effective ground control weapon since it can carry out reconnaissance at very low speeds and can be immediately ready for attack of any target which is detected. Other techniques for improving mobility and hence our ability to take and hold strategic points without the use of nuclear weapons also need critical study.

The above concentration on lightweight conventional weapons is based on our ability to maintain a continuous long range deterrent threat. In order to do this we must have a capability for an attack with large nuclear weapons. This capability must have the highest possible degree of invulnerability. In my opinion the missile-armed submarine which can launch its missiles from a submerged condition represents the ultimate in this area, and I might add that in my opinion it is the easiest possible technical job of all those we are attempting. The reason it will be the ultimate in this kind of weapon is primarily because technically it is almost impossible to conceive of any technique which would simultaneously immobilize all of the submarines which might be at sea at any given time. All of our detection capabilities for deep running, nuclear powered, submarines have very short ranges and unfortunately the ocean covers 75% of the globe. In contrast to the threat posed by a missile base in Norway, which is very specific and at least for planning purposes can be knocked out with one well placed

bomb, the submarine represents a threat from every point of the sea. Since the number of submarines at any position is unknown and unknowable, the degree of threat which is represented is a function of the psychological state of the enemy. The existence of the capability of launching missiles from any depth below the surface creates a threat which is capable of almost unlimited increase without the expenditure of funds for additional equipment.

I sometimes wonder what our reaction would be if we found the ocean was strewn with electronic transponders which would give a very accurate simulation of a submarine target echo to add to those which already occur naturally from schools of fish and kelp. (Such devices might be attachments to sharks and whales.)

By now I am sure that I have probably convinced you that I am working for the Navy, since I believe it is the Navy which has the best method of maintaining the deterrent capability necessary to prevent a nuclear war, and it is also the group primarily responsible for carrying out any operations which will have to be conducted away from our shores if we are able to prevent the nuclear war. I will, however, avoid any endorsement of the suggestion to combine the Army with the Marines, or abolish the Air Force, and summarize by saying that I am convinced that however the responsibilities are divided, we need:

1. Missiles to be launched from submerged submarines.
2. Nuclear powered, submarine transport.
3. Helicopters to carry supplies over mine fields.
4. Lightweight, inexpensive, individual air transport.
5. Hovering bombs using television cameras.

This completes the six year old prediction for the immediate future. Some of the predictions have been realized, but many still seem to be reasonable expectations for a few years more.

(Ref. 2) I might discuss now the results of a recent conference on Project Agile which was conducted for the purpose of advising ARPA on its role in weapons for limited warfare. The acceptance of non-nuclear warfare was general. The main concern was for mechanisms to establish operational research techniques to determine the effectiveness of our weapons. If, while we kill 10,000 people from an opposing force of 15,000, the opposition grows to 26,000, what would operations research say about the effectiveness of our weapons? This represented a kind of operations research which was new to me and would involve study of the combined military-social-economic program in order to arrive at a valid evaluation. We decided that we needed many types of surveys and very carefully conceived feedbacks to find the types of political activity and pressure which would be acceptable under the nuclear deterrent shield. Our own position must be made more positive. The Communists are proclaiming and teaching leaders in backward areas the skills to achieve the goal of world peace through world government. Do we have a program to match this challenge and the weapons needed to achieve it?

After considering such problems, the committee recomended that ARPA concentrate its efforts on non-lethal weapons and leave the lethal ones to the military services. This might be a course NOTS could consider following.

(Ref. 3) In replying to the Bureau's request for long range plans, we recently submitted the following:

"It would seem desirable to include in a report of this type information on those areas of work where estimates of technical progress show only very tenuous possibilities for improvements, as well as those areas which can be generally expected to produce effective improvements. The inclusion of such negative estimates would make possible the operation within a limited budget requiring the decision to drop some programs in order to expend effort in other areas. The following would serve as examples of the type of negative prognosis which might form both a justification for dropping certain projects and an inspiration for new methods of approach which would overcome presently foreseen trends:

(a) The ability of a submarine to avoid detection will increase at a more rapid rate than will the ability of our equipment to locate the submarine.

(b) The effectiveness of anti-ship missiles can be expected to improve more rapidly than the capabilities for missile defense.

(c) In a duel between two ships of otherwise equivalent capabilities, the victory is likely to go to the one best able to use passive means of detection.

(d) The ability of aircraft to locate target on the ground will not materially change and may even be expected to decrease due to the need for higher speed aircraft as ground defenses improve. This limitation will limit the value of close tactical air support until a mechanism for providing ground identification of targets and ground control of air-launched weapons is achieved.

(e) Changes in chemical propellant composition which will significantly affect ground-to-ground or air-to-ground weapons will not occur in the immediate future. Improvements in performance in these areas is more

likely to be achieved by the generation of new hardware concepts.

NOTS would add to the list on the positive side:

(a) The possibility of significant improvements in aircraft fire control systems by the use of closed circuit TV. The TV circuit provides for the location of computing sights outside the cockpit and can thus achieve variable magnification and large lead angles not possible with the techniques used during and subsequent to World War II.

(b) An anti-helicopter weapon for use by submarines can be developed utilizing the acoustic signals of the helicopter to trigger the missile firing mechanism.

(c) Techniques for generation of high electromagnetic fields may make possible warheads which might be effective in nullifying missile guidance circuits.

(d) Significant improvements in underwater warheads may be achieved by the use of a directed bubble collapse.

(e) A torpedo tube ballistic missile with ranges up to 1,000 miles can be developed and would provide improved NATO deterrent capability.

(f) Techniques using propellant and explosive compositions to generate large quantities of cloud nucleates are becoming available and show promise of large scale weather modification.

(g) The growing power of land based radars, together with the possibility that they might be operated synchronously, may make the semiactive operation of radars on airplanes and ships possible using illumination from ground installations. Such operation would contribute significantly to their ability to remain undetected."

One of the written questions presented to me prior to this meeting expressed the opinion that winning in a contest today required a combination of skills in social, science, economics, and propaganda, as well as weapons. How can a Navy laboratory, such as NOTS, help in this role? This is a very reasonable question and one whichis hard to answer since no single government organization below Congress or the Cabinet considers this whole range of problems simultaneously. If NOTS were to broaden its plans to include this range of activities, where would we look for support? Nevertheless, I think the need is so obvious and so great that we should again run the risk of being ahead of time and start making preparations to move in this direction, just as we started several years ago to move from nuclear to conventional weapons.

One example of the type of operation which might be successful is the Russian interdisciplinary Science City whose objective is to improve living conditions.

Our first small step is the establishment of the Behavior Sciences Group. Another is a contract by the Weapons Planning Group with the University of Utah to investigate social and economic factors in Southeast Asia. We need more steps, but we should expect progress to be slow. That is the nature of starting first.

Thank you.

Ref. 1 - Speech presented to the Underwater Ordnance Division, American Ordnance Association, Pasadena, California, 10 April 1957
Ref. 2 - ARPA Sponsored Conference, Rand Corp., Santa Monica, 8-9 Feb 63
Ref. 3 - Excerpts from NOTS Conf ltr of 18 Jan 63 to BuWeps, Ser 0101

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~~CONFIDENTIAL~~ - NOTS PRESENTATION, BuWEPS R&D PLANNING CONFERENCE
DECLASSIFIED DOD DIR 5200.9
19-21 November 1963 (by Wm. B. McLean, Technical Director)

Gentlemen:

Pls return to 17

Yesterday while sitting here, I began to worry a great deal about my speech, particularly when I made the quick calculation that the manpower and travel money represented in the room was probably spending our resources at the rate of about $10,000 per hour. I was afraid that I could not make a speech that would be worth that amount of money. Today I am glad to see that I do not have to undertake quite such a high financial responsibility as I would have yesterday. (Slide 1)

It is a little difficult to talk just about the programs of the Naval Ordnance Test Station without thinking about the Navy problems first. It is more important that we try to decide what is the over-all program of the Navy, and then see how the laboratories, with their particular facilities, can fit into this general over-all program. In fact, one of the things that is worrying us at NOTS a great deal is the thought that if the Navy goes in the direction that we think the technical pressures are forcing it in the next ten to fifteen years, we will need to modify our capabilities. We must modify the areas in which we are working so that we can still help the Navy. We see some of the things that we are now doing tending to disappear fairly rapidly. The rate of development of technology is so fast at present that the Navy is continually faced with the problem of making choices from among the many opportunities which are open to it. These choices normally require a balance between our present operational requirements, desirable operational procedures, and the kinds of possibilities for change which will result from this expanding technology. It is important in making these choices to recognize those areas where technical advances are not

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expected to produce significant gains, as well as to plan for the use of the gains which can be easily foreseen. We believe that the technical opportunities are available to the Navy in the areas which are listed here. (Slide 2) - In some cases, the realization of those opportunities may require considerable change in present operational concepts.

It would appear that the Navy's seabased deterrent system will provide an operational capability for a deterrent shield for non-nuclear warfare which will be very valid for a considerable period of time. (Slide 3) However, even though the ability to locate submarines which wish to remain hidden continues to be low and therefore our actual deterrent capability high, we should nevertheless continue to examine our deterrent shield. Familiarity with an existing system alone tends to lower the effectiveness of the system as a threat. It would, therefore, seem to be desirable to be continually making changes in the appearance of our deterrent shield, even though we may not significantly change its effectiveness in the event that it would have to be used. By making changes only in the appearance, we can probably keep its effectiveness as a threat quite high.

(Slide 4) - It would seem that the most critical problem with respect to most of our weapon systems is our ability to detect, to localize, and to classify targets, whether they are under the sea, on the surface, or in the air. We need creative breakthroughs in all of these areas of detection and it is vitally important that we work toward this goal with the hope that we will find some new techniques. We should recognize, however, that the probability of achieving such breakthroughs is not too high, and our future operations should not be planned on the hope of a technical breakthrough. We are liable to be in trouble if this is done. All of our known techniques for detection are sufficiently close to their

physical limits that we should be willing to run the risk of trying some very unconventional techniques. (Slide 5) For undersea targets, the physical bending of the sound rays, as NEL has so convincingly shown, would indicate that any appreciable extention of sonar range must come by getting the sonar detector down to greater depth. In this category, I think several of the laboratories are making proposals for sonar sensors operating at great depths such as SONORAY, LEPT, and the MORAY which we have been working on. I believe that all of these systems can offer some possibility of extending the effective range of sonar systems, but all of them have their particular kinds of difficulties.

The KELVIN wave patterns, which are produced at the surface by the passage of the submarines underneath, also show some promise of success in detecting submarines that do not operate at too great a depth, and to give the advantage of high scan rates from high altitudes. I think work to expand knowledge and improve techniques in this area should be continued and probably enhanced.

(Slide 6) - Frank Essapian, working in Florida, has demonstrated that porpoises can be trained to wear harnesses and pull various kinds of objects. This would prompt us to suggest that their use with a towed radio buoy for two-way communication is perhaps worthy of further investigation, both as a possible means of detecting underwater objects of all kinds, or for a use which is of interest to the Special Projects Group. This is the problem of protecting submarine tenders at places such as Holy Lock~~e~~ where you can not use anything that is explosive. Something that is quite gentle must be used. We have also been proposing that Cetaceans in general may contribute to a very important problem with respect to false contacts as seen by sonar operators.

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At the last Cetacean conference in Washington, the people from Woods Hole presented a very interesting fathometer record in which the bottom and the echo off the whale were visible, and then a nice strong echo that the whale was producing halfway between his present position and the surface by the simple mechanism of emitting pulses with the same repetition frequency as the fathometer. We do not know whether it is possible for all Cetaceans to produce such nice sonar pulses, but it is certainly something that could be investigated, if we can train animals in captivity to mimic any sounds that we put in the water in order to get whatever reward we have to offer. This is a program that could be very important to our understanding of false contact problems.

Other animals, such as birds, also offer opportunities for target detection. Because of the need of a bird to find very small objects on the ground from considerable altitudes, birds in general have developed a very high visual acuity. B. F. Skinner, in World War II, demonstrated that pigeons could be used to guide a missile. It does not seem outside the realm of physical possibility that homing on specific ground targets might be accomplished with birds if they were trained using techniques now being employed by Keller Breland, who worked with Skinner during the war, and who is now located at Animal Enterprises, Inc. He has developed a very interesting technique of training animals using computers. He says that when the people are out of the training loop, everything works much more rapidly. The computers are more patient, and the animals respond more reliably to computer training.

(Slide 7) - It seems inevitable that the natural future environment of the Navy will be increasingly below the surface of the sea in order

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to avoid attack by the air-launched missiles which we heard so well described by Captain Loomis. They probably also need to go below the surface from the standpoint of the second discussion we heard which was on chemical and biological agents. One of the ships we saw on the board yesterday looked like it was already designed to run below the surface just merely to get rid of the biological attack problem.

I might digress here for a moment to respond to the request of Captain Loomis to describe what the Soviet missile might look like. I do not have any real data on Soviet missiles, but it is possible to say what is the easiest kind of an anti-ship missile to build. From this standpoint, the Soviet missile ought to fly at Mach 0.9 and have mid-course guidance using bearing only, because that is the information that is easily available to them from either our active sonars or our active radars. It is available to the Soviet launching ships from ranges as great as the maximum range of any of the missiles which were listed. If we put in simply a pre-set magnetic course to a missile that is designed to guide on altitude and bearing only, then you come up with a missile that probably flys as low as it can and still keep above the waves, perhaps 50 feet. It has a big advantage if it can fly at an altitude that is below the freeboard of the target that is being attacked because then it does not have to control at all in elevation. With such a missile, it is easy to calculate that if you had as much as a three-mile homing range, the turning radius will allow a hit on any ship which comes within the field of view. Therefore, the missile should have an active radar homer which would start about ten to fifteen miles before it reaches the ship, and simply keep the missile pointed at the ship as it comes in. This is a very simple kind of a radar

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homer to build because high frequencies are not needed and fixed antennas can be used. This is a missile I think we need to worry about, and I do not think any of our missile systems can touch it because of the very short reaction time available after a missile of this kind comes over the radar or visual horizon.

We also know a lot about the ocean. We have heard a lot about the lack of information on the ocean. I am not sure this is true. Specifically, we know that the characteristics of the ocean are such as to insure its continued existence as a good, safe hiding environment for vessels which want to remain hidden. Our present knowledge would lead us to expect that tremendous further advantages in using the ocean will accrue to anyone who wants to learn more about bottom topography, undersea currents, deep scattering layers, etc. We can foresee an expanding need for the vehicles and equipment together with the training programs which will allow us to explore and exploit the undersea environment. When the United States establishes mining claims and oil wells on the bottom of the ocean and begins to plant ocean farms in the volume of the sea, it is clear that the Navy will be called upon to provide legitimate access to these resources in much the same way that it now protects our other maritime interests such as fishing.

(Slide 8) - However attractive the picture of the complete undersea
may be
operation, it is clear that our development work is not now at the state which will allow such operations to be a reality in less than ten to fifteen years. While we are expanding our development work in undersea operations, we also need to improve our capability to operate on the surface. It would seem that one of the quickest methods of achieving this would be the improvement of our capability for passive operation. Ships running in

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close convoy, using any type of electromagnetic radiation, make themselves very good beacons for homing missile attacks. By the nature of the problem, it is obvious that a missile can be designed which can always be launched from beyond the range of any conceivable shipboard system. (Slide 9) The enemy's problem in attacking our ships is greatly increased if our ships move apart and try to run passively. From the development standpoint we ought to begin the investigations of semiactive operations in which moving vehicles, such as ships and aircraft, only listen for echoes produced by active sources which are land based. Dr. Christensen tells me that this work is now being started at NEL, but that it needs to be greatly increased since they are doing just paper investigations. To solve this problem, we need research and experimental tests.

Large numbers of less expensive ships will both increase their coverage of the ocean and decrease their total vulnerability from an economic standpoint. It is for this reason that we have proposed such radical concepts as a sailing catamaran as a listening platform for both sonar and electromagnetic radiation. Such a ship may represent a step backward in the Navy, but would also provide a very long cruise range without the requirement of refueling. It would have ideal passive listening conditions. Large sea planes, such as the one we were shown in the Soviet armory, which can land on the open ocean to listen, also provide the possibility of large coverage with a good passive listening capability. Douglas Aircraft has also proposed a similar machine, the Weiland machine, which utilizes the ground effect in order to carry the big loads which are needed for long range operations.

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(Slide 10) - Limited Wars, which we can expect to be an increasing area of interest to the Navy, require skills more closely related to police activity than to the destruction which we normally associate with warfare. I think that small nations cannot be expected to look for protection to an organization whose only weapon would involve their general destruction. We need to do much more work in the Navy in the development of training aids and instruction methods which will allow us to express modern technology in terms which can be understood by indigenous groups. From some of the things we have heard here this week, we probably also need these training aids and instruction methods to allow us to explain our modern technology to our own operating personnel. Many of the limited warfare goals must be accomplished by influence rather than force, and this gets to be an area in which it is hard to justify military support. We need to provide tools which will not generate high emotional reactions. Our experience in Viet-Nam shows that it is possible to kill off more enemies than exist and still have an opposition of increasing strength if the wrong tools are used. Non-lethal BW and CW agents may be developed as such tools if we can find a way to properly couple them to economic, political, and educational programs. In this area we face a very hard problem because of the way government operations are divided.

(Slide 11) - Another interesting possibility for exerting influence is through the use of tactical weather modifications. The results we have achieved to date with silver iodate as a pyrotechnic agent make possible the production of cloud bursts of considerable violence. The same material can produce increased snowpacks, modification of hurricanes, and similar phenomena.

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Other materials seem to offer the promise of fog dispersal. Many societies we want to influence still express their control of environment through the influence of the witch doctor. If we could have a real positive display of weather control which is easy to recognize, we provide a tool by which the authority of the witch doctor can at least be challenged.by a mechanism which people can understand.

In the past, our measurements on the effectiveness of warfare have been concerned, first, with the destruction of enemy forces, and more recently with the complete destruction of the enemy. (Slide 12) I think you have all been faced with the problem of expressing weapons capabilities in terms of cost effectiveness and have had the hard problem of trying to decide what measure to apply to cost effectiveness. Is it just a comparison between weapons, or is it the cost of killing people? It is obvious that we have nearly achieved the complete attainment of the objective of destruction from a technical standpoint. Our 1 megaton, 10 megaton, 100 megaton bombs are certainly the highest order of cost effectiveness in terms of area destroyed. But we are now faced with the problem of limiting warfare, and this limitation might properly be renamed total war in that we are no longer concerned merely with the tools for destruction, but must add to our capabilities for influence such things as politics, mutual interests, information exchange, economic warfare, and all of the other things which go into the creation of both our own behavior and the behavior of the people we would like to assist.

(Slide 13) - Much of our past technological accomplishment has been guided by the goal of more destruction. Anything which showed the possibility

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of more accurate delivery of greater destructive capability at longer range has been pursued without examining its effects on the furtherance of our Nation's political aims. We vitally need studies which will both clarify our political aims, and allow us to choose from among the large maze of possibilities those systems which will be most meaningful in their contribution to the balance of national power. Cost effectiveness in this sense needs a better figure of merit than those determined by the expression of kill radius, or the probability of kill, or just counting up the bodies. We have established a behavioral sciences group of fairly modest size at the Station to help us in the study of some of these things. I feel that their influence has been very great, and in particular their work has highlighted the importance and the great difficulty of communications. This difficulty has also been highlighted by the meetings we have been having here this week. I have been convinced that the Navy and the Department of Defense suffer from a very serious communication problem which might bear some more research. Everyone, I think, has spoken of the difficulty of supplying information and data which is required in ever increasing volumes. I would like to say a little bit about some experience I have been privileged to have in serving on a DOD committee for limited warfare, and then more briefly on a similar committee at the Presidential advisory level. These two experiences, together with my regular job as laboratory director, allow access to information at widely separated areas in the government. One of the first things that struck me is that I do not recognize some of the people you are describing this morning as keeping the bureau in continuous trouble. It is very disturbing to see the distortions which the communication channels we have established

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can introduce in the information we would like to transmit. I believe that everywhere in the government you find very dedicated people who are doing their very best to further the national program and national defense. But the misunderstandings which arise in the transmittal of information may very well bring us all to a standstill unless we can put our knowledge of communications and human behavior to work in providing the information which seems to be such a crucial problem.

For good communication I think our behavioral scientists would say that we need a transmitter and receiver who have a common language which is based on a common background of experience. Since these very seldom exist, we have to correct errors in communication by a two-way exchange which will help us develop a mutual understanding and a mutual confidence in the integrity of the individuals and in their thinking processes. Without this two-way spoken exchange, I think it can be demonstrated experimentally that you can almost always generate a conflict, or on a more drastic scale, a war by limiting the transmission of information only to written documents. The things we have been saying the last two days indicate that we have a great lack of many of the vital elements necessary to good communication. Personally, I have been sitting here for the last two days with the great itch to ask questions, and feeling considerably restrained that I did not have a chance to correct some of my impressions which I felt were being generated by the things being said. My only chance for spoken exchange occurred at the recesses and cocktail hours which tended to be much too short. I would therefore like to take the chance before I quit today - because I think it is going to be the last chance I get to say anything at the meeting-- to try to put in words some of the impressions which I have generated, even at the risk of generating more misunderstanding. I am sure that

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my impressions are generally inaccurate, and that they must be corrected before my further work can be effective.

The first impression was that the Navy position, as represented by the speeches made by CNO on Tuesday, has not had sufficient contact with either the technical bureaus or the Navy laboratories to provide the presentation with a clear technical background for its program or its requirements. I think we have failed as technical advisors to CNO in providing a sufficiently strong technical program to allow them to get the Navy's money through the kinds of fairly clever technical people who reside in DOD. It is unfortunate that the people in DOD have sufficient time, while CNO does not, to come out and contact all of us at the laboratories so that when they come to one of these briefings they know a heck of a lot more about the Navy's program than the people who are making the presentation. This is something I feel we, as laboratories, and as bureaus, need very much to correct.

I also have an impression that the people here in the bureau feel that the laboratories only think about components and are quite provincial. I got the same impression of the bureau programs in that eabh vice president seemed to be much more interested in their assigned areas than in the overall program. This impression is probably created by the fact that I did not hear any exchanges between areas. I did not hear any discussion of the relative merits of a ship-launched cruise missile versus an air-launched anti-surface missile. We did not hear much about how you incorporate a component, such as an aircraft, into a total fighting system. And we did not hear too much about why it is we need new aircraft as opposed to missiles. I am sure that if we had asked a lot of questions we would have probably been here for six weeks in trying to clarify some of the problems that such a discussion would have raised.

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My last impression was that all of us in the Navy have a tendency to concentrate our major efforts in areas where we have very real and urgent needs, but we also have sufficient information and knowledge to know that progress is not going to be very likely. I think we might study our programs and see if we could work better in areas where knowledge is lacking, or where more than adequate knowledge is available to make progress very quick and easy. For example, I think that the ASW problem, amphibious landings, protection of the surface fleet, development of anti-missile missiles, development of all weather systems which are countermeasure proof, can be shown on purely technical grounds to be nearly impossible, however desirable they may be from an operational standpoint. On the other hand, STOL aircraft, missiles to attack any target that can be located, torpedo countermeasures, submarine transport particularly of petroleum, oil, and lubricants, reconnaissance drones, and satellite reconnaissance vehicles are all areas where designs could be accomplished with very little further research. We know how to do these things. In the areas where we need more research, we have weather control, vertical take-off and landing, although I understand the Lockheed Humming Bird was displayed on television this morning and indicates to the Navy that this is now technically feasible. We need more research on the use of animals for detection, the use of non-lethal biological and chemical warfare, the use of color as a detection aid in sonar, radar, and IR recognition. We need more work on passive fleet operation, reconnaissance countermeasures, and secure continuous communication. I think in these areas, if we expended some money for research, we could achieve high gains very quickly. In particular, I would like to say that I think this meeting has been very valuable in showing how much our communications need to be

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improved if we are to achieve a Navy program which has a chance of being funded through a group of the high technical competence which has been collected in DOD. Research on communications of this type, which is possible I think through some of the techniques of the behavioral sciences, should have a particularly high payoff. I hope that the laboratories can help in this area, if we work hard enough.

Thank you.

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DOD DIR 5200.9

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DEPARTMENT OF THE NAVY
U. S. NAVAL ORDNANCE TEST STATION
CHINA LAKE, CALIFORNIA 93557

IN REPLY REFER TO:

PRESENTATION TO JASON DIVISION, IDA, FALL MEETING, 31 October 1964, Arlington, Virginia, Wm. B. McLean, Technical Director

I have been asked to discuss with you today some of the problem areas in limited warfare for the purpose of highlighting those areas where technology might be of assistance. About the time that the work on the POLARIS missile started, and it became obvious that an invulnerable shield could be established, we at the Naval Ordnance Test Station became concerned about the kinds of activities which might result when the stable deterrence situation was established. With the country's experiences in Korea as a background, it was obviously possible to fight an extended war with conventional weapons and not have it escalate to the use of nuclear weapons. NOTS therefore chose the area of limited warfare as a prime interest for our organization as early as 1957. (Movie on limited war presented in 1961)

We have found that in this area design criteria are extremely difficult to select. The military aspects of the operation tend to merge with the political, economic, social, and educational parts of the problem. Warfare has long influenced the behavior of groups of people by threatening their destruction and the demonstration of the ability to carry out the threats by the actual destruction of part of the group. Now that we can wipe out the whole group nearly instantaneously, some other measure of the effectiveness than kills-per-dollar must be established. The behavior of a dead group is difficult to influence. We at NOTS have been attacking the problem of developing selection criteria through the use of the behavioral sciences. We have studied value systems in different cultures and the reactions of groups of people in situations of high stress. Such studies would show that graduated responses, consistency of reaction, and invulnerability to counterattacks are very important characteristics for our new weapon systems. Of course the most disturbing input from the field of the behavioral sciences is that threats in general have a low probability of influencing the behavior of either individuals or groups without inadvertent or unintended and undesirable side effects.

Our struggles to find a firm basis for the weapons systems of limited warfare are generally resolved by analogy. The military parts of the operation will probably be similar to those of a police force which treats the exceptional cases while operating under a body of law which handles the great bulk of the causes for dispute. At present, the body of international law is still forming and no organization yet exists which is charged with the responsibility of supporting the law or of soliciting the services of an international police force. Until such an organization can be established, it will be the responsibility

of the major powers, hopefully with mutual agreement, to carry out the police actions needed to stabilize the world. We can classify the expected "Police-military" operations in three categories. Number (1) is the transportation and the maintenance of paths of communication from our home base to the site of operation; (2) is the location and identification of those responsible for distrubing the peace; and (3) is the correction of the problem behavior.

TRANSPORTATION

For the United States, most of the limited warfare or police-type operations which we can visualize will occur at places which are accessible only by water or by air. This includes those difficulties which might arise in South America. Overseas transport is therefore one of our prime problem areas. Our cargo ships can be expected to be subjected primarily to attack by air and land-based guided missiles, and secondarily to submarine-launched missiles and torpedoes. Our air transport can be expected to be highly vulnerable to anti-aircraft missiles located near the points at which we must land. In fact, the guided missile seems to me to have made the accumulation of large quantities of materials in any easily visible location a thing of the past. The only solution which I have been able to devise is over seven years old but is as unacceptable now as it was when it was first proposed. I believe we could support troops in any place in the world if the long transport problems were to be accomplished by the undersea route. Storage near the scene of operation should also be in watertight containers on the bottom of the ocean rather than on beach heads. Final transport will depend on a minimum exposure time, and I would visualize it as being direct from the undersea location to the forward battle area through the use of vertical take-off vehicles. Your help in coming up with better or more acceptable solutions would be much appreciated.

Before we can achieve any reasonable degree of undersea transport, however, we will have a considerable period when our surface ships will have to carry out the operations independent of the dangers which may beset them. Since the ocean is large and ships small and hard to find, these dangers can be materially reduced if we can devise a system which will allow our ships to perform their necessary functions without signalling their location through emitting electromagnetic radiations. We need better techniques for passive operations.

LOCATION AND IDENTIFICATION

In limited warfare a location of groups requiring restraint and correction is nearly as difficult as in any other type of police operation. As we have found in Vietnam, the enemy is not clearly distinguished from friends. Errors.in discrimination can produce the type of result where we start with an opposition of 5000, we kill off about 10,000 of our opponents, and then find we are faced with approximately 25,000. Need for distinguishing between friend and foe is urgently needed. The obvious

technique of lie detection through physiological measures proves to be relatively unacceptable in an oriental culture.

We are also developing ground-to-air missiles which will make the operation of all aircraft in the battle area very hazardous, particularly if they are subjected to fire from both sides of the front. The present state of our equipment for identification of friend from foe makes operation of aircraft over the front lines very hazardous. IFF is a fertile but difficult area for technological improvements.

Our new antiaircraft weapons force our attack and interdiction aircraft to fly low and fast. Thus the requirement for safety makes the detection of targets on the ground extremely difficult. I will show you a movie indicating the problems of air-to-ground recognition of targets. (Show COSO Range movie)

CORRECTION OF BEHAVIOR

In the final analysis, execution of our national goals will require man to man contact on the ground under conditions of high stress. For success we will need clear political and economic goals and the creation of the social pressures which will implement these goals. Effective nonlethal weapons should give us the capability for rapid mass action and the generation of time to carry out the separation of friend from foe. All of the underdeveloped countries have a great requirement for technical information in order to raise their standards of living. The Communists in Southeast Asia have for the last ten years been exploiting this need by selecting the brightest young men from the more remote tribes and offering them technical fellowships in China and Russia. These courses of study include modern techniques for industrialization and the improvement of the agricultural output of the community. They also promote an understanding of group control, resistance through sabotage, and the organization of close family groups for participation in the world wide movement for a stable peace through world organization. We now face a 10-15 year handicap in this race for the training of future natural leaders. Perhaps our greater capability in technology will enable us to develop a machine teaching procedure which will provide a larger number of potential leaders with the technical education, the political goals, and the strong belief in the rights of all men to act as the individuals who will give us an antidote to the pressures which the communists have been creating through their educational program.

I would like to conclude my discussion with a review of an important problem which is generated by our government organization and which I believe can be resolved only by well informed technical inputs. This difficulty starts with the assumption that military development work should be done in accordance with a requirement proposed by the military services. Very reasonably, the most needed of these requirements will involve techniques which have not yet been developed. Therefore, some of them are likely to be impossible.

The requirements then pass to a group of technical organizations in industry, government, and universities who have achieved their success in life largely through their unwillingness to admit that anything except perhaps perpetual motion is impossible. And when one sees the aircraft carrier ENTERPRISE running around the world without need for refueling, even perpetual motion seems to be possible for all practical purposes. We thus have requirements being generated by a group with a high record of achieving the nearly impossible. To these two groups we now add the management and the accounting organization whose function is to see that objectives are clearly planned and that expenditures are adjusted so as to achieve these objectives according to plan. One of these people once told me that the management of research projects should be easy. Periodically one should observe the rate of progress toward the planned goals and add money to those projects where the progress is slow. When asked how this was possible under a constant budget, the auditor replied that this would of course require removing money from projects which were progressing rapidly. I think one can see that if this open-ended process is allowed to continue without feedback that all of the effort in the country will ultimately be expended toward the achievement of impossible goals. I believe that this is the basis of some of the very difficult decisions which the Department of Defense has recently had to make on the cancellation of major programs. For this reason, the government urgently needs the assistance of the best technical minds in the country in order to decide where progress is approaching real physical limits and additional expenditures will have a low payoff. Such a study is fully as valuable as the other side of the coin where we list areas where information is so meager that high rates of progress can be expected. As an exercise, NOTS has attempted to put our programs in three categories, the first being the one in which we have sufficient knowledge to know that progress is not going to be very likely. This category is small but unfortunately includes some of our most urgent military requirements. The second area is that in which adequate knowledge is available to make the development of new equipment quite rapid on an engineering basis. Unfortunately these projects have also tended to be low in priority in the military requirements list. The third category is the one where we see a need for more research. This is the area in which we have insufficient information to either prove or disprove the practicality of a new military development. In this category we have put such things as weather control, vertical takeoff and landing, the use of animals for detection, the use of non-lethal biological and chemical agents for the accomplishment of military purposes, the use of color as a detection aid in sonar, radar, and IR recognition, the problems of passive fleet operations, achievement of IFF and secure continuous communication. I am sure that this list is indefinite and rapidly expanding but can be completed much more quickly from the knowledge of the limits of present understanding than from the knowledge of the gaps in our military operational techniques. It is in this third area that we need to encourage the management of their own programs by all research organizations.

Ocean Exploration and Antisubmarine Warfare

This section contains the following speeches in chronological order:

"What Next After Guided Missiles?" presentation to the Navy League, Houston, Texas, 27 October 1958

McLean suggests that now that we "have all the basic concepts and have demonstrated the workability of practically all the missile types for which we can see any need," new areas for exploration might include high-speed submarine transport and undersea mining.

"Comments on the Future of Naval Warfare," presentation to the Committee on Undersea Warfare, Panel on Submarine Studies of the National Academy of Science, 17 November 1959

McLean urges recognition of technical trends that make "oceanography in all of its many aspects ... of continuously increasing importance to weapons developments of the future." He recommends that the Navy "begin to plan for the type of warfare in which undersea operations will supplant surface operations at a continuously increasing rate."

"Moray Presentation," presented to Panel on Deep Submersibles, Committee on Undersea Warfare National Research Council, National Academy of Sciences, 13 September 1960

In this overview of the Moray two-man, deep-diving submersible vehicle, McLean offers a description of the proposed vehicle, emphasizing its promise for a myriad of tactical applications, including replacing "all of the functions which are now carried out by homing torpedoes." In response to a question of why the Moray development should be carried out at NOTS, McLean answers that "it would utilize the particular skills we have available, and ... we think it would be lots of fun to try to carry it out."

"NOTS Concept of Future ASW Weapons Systems," presentation at Undersea Warfare R&D Planning Council 16th meeting, Panama City, Florida, 11-13 December 1962

McLean discusses the reasoning that led to the development of Moray as an antisubmarine weapon. He also describes his concept of a small, long-range, airfoil-propelled patrol craft, a type of ship that he says would be much more effective as "a police force on the high seas" than would other alternatives (such as Seahawk) then under consideration.

"NOTS Presentation on Moray," presentation at Undersea Warfare R&D Planning Council meeting, Ft. Lauderdale, Florida, 4-6 February 1964

Summarizing progress on the Moray submersible vehicle, McLean describes Moray's main function as "the provision of a weapon to surface ships which would discourage their attack from submarines under the conditions of limited war."

"Future Exploration of the Ocean," presentation at Symposium on Modern Developments in Marine Sciences, American Institute of Aeronautics and Astronautics, Los Angeles, California, 21 April 1966

The study of the ocean, McLean states, "far from being a single discipline, has something for every conceivable scientific and engineering skill." He briefly discusses glass submersibles, deep-diving underwater vehicles, and laboratories on the sea floor as fruitful areas for exploration.

"Survival of the Navy at Sea," NUC Technical Director Symposium, San Diego, California, 8 January 1975

From his perspective as Technical Director of the Naval Undersea Center, China Lake's sister laboratory in San Diego, McLean offers predictions on the future needs of the Navy, arguing persuasively that "if the Navy wants to continue to survive on the surface and under the sea, it must start necessary research to build undersea transport . . . to supply the numerous small ships that it will need in order to exert political pressure in all areas of the world."

PAPER FOR PRESENTATION TO NAVY LEAGUE, HOUSTON, TEXAS, 27 OCTOBER 1958

BY WM. B. McLEAN

WHAT NEXT AFTER GUIDED MISSILES?

You have invited me to talk to you about the Navy's missiles on an unclassified basis, which means I can't go very far into any technical details. It has been ten years since the design of SIDEWINDER was started and since the early versions of TERRIER and TALOS were brought to the Naval Ordnance Test Station by the Applied Physics Laboratory at Johns Hopkins University for testing as part of the BUMBLEBEE program. Starting even before then, for approximately fifteen years the United States has been putting a large proportion of its military budget into the design and construction of guidance equipment to allow the delivery of warheads to specific points at longer ranges and with more accuracy. From a conceptual standpoint, this field has now been very effectively explored. We have inertial platforms which can keep track of the motion of a missile and correct any errors which may arise due to winds, variation in thrust, etc., and correct the motions so that if the final objective is known in terms of the starting point the missile will get there. In terms of improving the range, we have gone from the 250-mile range of the V-2 to 1500, 5000, and then into orbit about the earth. Rockets to go to the moon have been built. It is safe to say that increased range of weapons has lost much of its past importance in the same manner that increased size of warheads has lost its meaning.

We now have all the basic concepts and have demonstrated the workability of practically all the missile types for which we can see any need for. At the same time we still have a long way to go in the engineering to improve the reliability and producibility of these systems. The gap between demonstrating a workable model and being able to produce this model at a high rate with high reliability is something with which every production organization is intimately familiar. We seem to have forgotten this time lag in some of our missile work and are very concerned when first models off the production line won't work. Given sufficient time I am sure we will have cheap and reliable missiles to track down aircraft out to any range where they can be located, attack surface ships from either above or below the surface, attack aircraft from the ground whenever they can be located and identified, and fire ballistic missiles with good accuracy as far as we wish.

We, at the Naval Ordnance Test Station, spend a great deal of thought on the problems of trying to keep our thinking ahead of the present trends. We need to build on our past experience and project our new designs into the future. We can improve these possible designs by discussing them with the people concerned and thus find and correct defects. Since I believe the oil industry has a major role in future military problems I consider it a rare opportunity to try out some of these thoughts with you.

Let us assume that all these missile objectives for which we are now spending our money have been accomplished and ask what is now our possible military position and where do we go next. The balance sheet will probably read:

1. The importance of manned aircraft will have been materially reduced.

2. Surface ships will be very vulnerable to attack.

3. The air-to-ground picture will be no better, and due to ground defense against aircraft we will be left with a limited capability to attack ground targets.

4. Our capability to attack submarines will not be materially different.

In all of these areas the limit will not be set by the ability of a missile to guide, but by our ability to recognize a target against the background. This principle might be summarized by saying that in a missile age, a target which can be located can be destroyed.

Where does this leave us? At present we have two types of target which are particularly hard to locate--the foot soldier and the submarine. The foot soldier will always be with us but somehow we must get him to the points where he can act. In an advanced age the submarine seems to me to be the only logical answer for advanced transport. If this is to be accomplished, the same arguments which produced a joint industry-government build-up of naval surface transport and commercial shipping need to be applied to submarine transport and its commercial uses. This is where your interest might be vital.

In the space age we discuss freely the fact that the moon might have valuable mineral deposits which we could explore and mine. On the other hand, the moon is supposed to have been thrown out of the Pacific basin, and only the edges of this basin have been explored. We wonder about the back side of the moon and forget that a larger percentage of the surface of the moon is visible than is the surface of the earth exposed to our view. We now have the techniques to survey the whole surface of the earth under conditions no more inhospitable than those on the moon. The nuclear-powered Nautilus shows the way to unlimited endurance under water and the bathyscape demonstrates the techniques to withstand the pressures at the greatest depths. We believe that coring operations can be conducted at the bottom of the Pacific, and plans for such operations have been considered. If mineral or oil deposits are discovered here, as I am sure they will be, the transport problem will be hard, but still infinitely easier, than from any location on the moon. Oil will pump itself to the surface and its transport, submerged in bags protected from the effects of surface storms, should be easy.

The greatest handicap to this kind of exploration is an instinctive fear of underwater operations. The growing group of skin divers will help to overcome this fear. If we can follow this with high speed submarine transports which make use of television to show passengers what is going on in the water outside, and allow them to see the surface storms pass harmlessly overhead while everything is quiet below, I believe the reluctance toward underwater operations will rapidly disappear. Surface ships are basically limited in speed by wave drag. Submarines are not so limited. The submarine having positive buoyancy and diving using hydrodynamic forces, the underwater equivalent of the Zeppelin, has not yet been tried. It should be very safe, very comfortable, and capable of traveling the Northwest Passage around the top of North America. The drag of a submarine goes up as the square of its dimensions while its capacity increases as the cube. Therefore, just as for surface transport, the bigger the ship, the cheaper and faster it can carry cargo.

To summarize, we need commercial submarine transport because:

1. It provides nearly perfect protection in war time.
2. Three-fourth's of the earth's surface is under water and is now unexplored for mineral and oil deposits and we need ships to get there.
3. Submerged transport will be free from weather.
4. For many incompressible cargoes, such as oil, submerged transport could now be cheaper than surface transport.
5. The submarine is a good simulator for space travel and its widespread use will help us solve the many problems of living in sealed containers.

Having gotten back to space ships, I might say something about our neighbor, Venus. Venus has an interesting atmosphere containing CO_2, ammonia and methane. It is the kind of an atmosphere one might expect if the elements on earth were mixed up in a molten state and allowed to cool so that the oil and coal deposits were combined with the oxygen of the air to form the more stable CO_2. I have heard it calculated that if plant spores of the proper kind were to be introduced on Venus they could, by photosynthesis, absorb sunlight and convert the atmosphere of Venus to one like that of earth in about 3000 years. This is a project we should start now so that when we have completed the submarine exploration of our world we will have another more hospitable world ready to explore with our then more advanced techniques.

UNCLASSIFIED U. S. NAVAL ORDNANCE TEST STATION
China Lake, California

[redacted] Code 01

Presentation to the Committee on Undersea Warfare, Panel on Submarine Studies of the National Academy of Science, 17 November 1959, NOTS

Comments on the Future of Naval Warfare - Wm. B. McLean

I would like to make some comments today on our visualization of future naval weapons trends. Our initial assumption in planning for future naval weapons rests on the belief that a stable deterrence to nuclear warfare will be established. This stable deterrent situation will come about due to the fact that the Soviets can get all of their objectives for world domination without the use of nuclear warfare due to their shorter lines of communication. It is therefore in their own self interest to avoid the initiation of any nuclear conflict.

Since the United States has no goals of conquest and a long background of refraining from warfare until it is forced upon us, it is difficult to believe that we will initiate the first use of nuclear weapons. It has often been argued that we might conceivably initiate the use of nuclear weapons at sea where there would clearly be no non-military involvement. However, we will be restrained in such an initiation due to the fact that nuclear weapons represent a bigger margin of gain with respect to the attack on aircraft carriers than they do with respect to the attacks on submarines. It is therefore to our own self interest from a military standpoint to hesitate in the use of nuclear weapons at sea.

Russia can be expected to continue her advance toward world domination by such small steps that they will never constitute sufficient provocation for us to initiate all-out war. If we are to accomplish an effective opposition to these continual losses, we must have the capability of establishing a police-type activity. This activity will require fast acting, surprise task forces to carry out actions commensurate with the degree of force required to oppose the threat. Any such actions carried out by means of conventional weapons will impose a serious sea transport problem. The USSR has anticipated this problem and has visualized the fact that our only access to other nations is by means of the sea or by air. Her concentration on the building of submarines since World War II and their transfer to other nations, such as China and Egypt, is well calculated to hamper the overseas operations of our present fleet without involving us in an all-out attack by Russia. Since the United States has concentrated its attention on aircraft carriers, guided missile cruisers, and other surface vehicles and has, to a large extent, ignored the capabilities of the submarine we have a strong reluctance to face the technical facts of the relative capabilities of ships and submarines. From a technical standpoint rather than a tactical one, it would appear obvious that further developmentw will continue to widen the gap which exists between ships and airplanes. As soon as the speed of the submarine passes that of the surface ship there appear to be

no foreseeable merits of traveling on the surface which will again make the surface ship superior to the submarine.

Our weapon technology has now advanced to the state where missiles can be made with sufficient propulsion and adequate guidance to be able to attack any target which can be detected and classified at the maximum classification range. This is true whether the missile be launched from submarine, ship, or aircraft. The relative vulnerability therefore hinges on the relative detection and classification ranges of each type of carrier for the other and it is quite obvious that with equal technical advances the surface ship will always present an easier target for the submarine or aircraft than will these attackers present to the surface ship. All of the effects of miniaturization are such as to continually degrade the advantages of size which the surface ship has up to now enjoyed.

We believe that it is important to recognize these technical trends as early as possible and to begin to plan for the type of warfare in which undersea operations will supplant surface operations at a continuously increasing rate. The first step in such a program should be the undersea transport of gasoline and oil. Since these represent nearly 60% of our total overseas cargo and they are in such a form as to be easily packaged so as to stand submerged transportation, their transport below the surface will make it possible to transport people and other equipment by air.

Our next step would be to provide each surface ship ~~surface ship~~ with an undersea fighter to help even up the exchange rate between surface ships and submarines. If this can be accomplished, the lower cost of construction of surface ships will become an economic advantage in a limited type of operation. Eventually we should be able to look forward to a complete undersea expeditionary force to move in on key objectives and launch a large number of attacking personnel from the sea on one-manned, rocket-propelled gliders. Such troops could move in for surprise attack without depending on landing facilities or beach installations and could proceed directly to the critical area for attack. The weapons for use by such an expeditionary force and the vehicles to carry them are all problems which yet need to be solved.

Our belief in the growing use of the volume of the ocean below the surface requires a continually increasing knowledge of the conditions which exist below the surface and of techniques to better utilize these conditions for hiding and attack. We therefore believe that oceanography in all of its many aspects will be of continuously increasing importance to weapons developments of the future. It is with these facts in mind that we are actively engaged in setting up an oceanographic research group to assist the other groups throughout the country working in this field. We expect that by their contacts they will make the knowledge of oceanography available to our weapon development groups in the same manner that our chemistry, and other research physics groups cover their special areas.

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UNCLASSIFIED

13 September 1960

MORAY PRESENTATION

to

Panel on Deep Submersibles, Committee on Undersea Warfare
National Research Council, National Academy of Sciences

by

Wm. B. McLEAN, Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

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Initials Ray George

We started the thinking process on this vehicle using the data available for the aircraft torpedo Mk 46. This vehicle is one-foot in diameter and is designed to travel at 45 knots. If we scale it up in linear dimensions by a factor of 5, we arrive at some of the characteristics which we would like to build into the MORAY vehicle. For the Mk 46 we have demonstrated active sonar ranges out to 2,000 yards in the water. If we assume that the sonar range might scale proportional to the dimension, we should then have an active range for MORAY of the order of 10,000 yards. We can assume that the drag will go as the square of the linear dimensions, but the volume available for fuel will go as the cube of the linear dimensions. At a 45 knot speed, MORAY might therefore be expected to run for the order of an hour and a quarter. If we can shift gears, by either using a piston engine or multiple turbines, so that the fuel consumption will vary as the velocity cubed, then we should have 28 hours at 15 knots, which we believe is an adequate cruising speed and time for most of the applications which we have in mind. With this kind of scaling, roughly half of the weight of the MORAY vehicle must be in fuel and oxidizer. We could use some of the exotic fuels with high energy contents which are being developed for torpedo propulsion, but the high requirements for safety which are demanded by having men present leads us to the belief that the fuel combination we should consider is hydrogen peroxide and diesel oil. It would seem that a 1,000 hp closed-cycle steam engine would be something that would be readily available on the commercial market. We have, however, found by investigation that this is exactly the wrong size. Engines of 100 hp have been developed and tested and similarly engines of 10,000 hp and up are readily available. One of our first problems, therefore, is to demonstrate that a 1,000 hp steam engine can be built together with the heat exchanger necessary to drive it. We need also to demonstrate that hydrogen peroxide and diesel oil will burn stably in a combustion chamber at a pressure of the order of 2,000 pounds per square inch. The gases from this combustion process would then be passed through a heat exchanger and allowed to dump overboard in the cooled condition through a relief valve. We believe that such a system is practical because the heat transfer in a boiler improves with increasing pressure, and, in addition, the water vapor at high pressure will condense at a sufficiently high temperature that the condensation products can be used to provide heat to the working cycle of the closed-cycle steam engine. This recovery of the heat of condensation from the water vapor is particularly important in case it becomes necessary to use large quantities of cooling water in the combustion process.

We might now cover some of the things which are known about the Mk 46 torpedo which we think will be applicable to the MORAY system. We have carried out experiments on self-noise of the torpedo, and on the use of gas shrouding to reduce propeller noise. These results would lead us to believe that the larger vehicle with less rapid changes in contour will not suffer excessively from self-noise even at speeds up to 45 knots provided the surface finish can be maintained for this vehicle at the

high polish maintained for the 12-inch diameter torpedo. By the use of simulator studies we have been able to design control systems for the torpedoes which will allow them to run stably in either the positively or negatively buoyant conditions. We believe these same simulator calculations will apply directly to the dynamic stability of the MORAY vehicle. Gears with a high noise reduction have been developed for use in the torpedoes. These same techniques should be useful for MORAY. In addition, a heat exchanger which uses propellant gases for its source of energy has been tested for the Mk 46. We would contemplate extending these same techniques into the larger dimension vehicle. We believe that sufficient data already exists on the habitability of a 5-ft diameter sphere by two people. This diameter, we find, is larger than the cockpits of most two passenger airplanes, and considerably larger than the inside dimensions of a Volkswagen.

The question is frequently asked as to why, since MORAY is a weapon, we should not put one man in the vehicle instead of two. In Germany during the last war both kinds of vehicles were tested. The one-man vehicle had little operational success, whereas the two-man vehicle proved to be entirely successful. In our own case with night fighter vehicles the addition of a second man greatly improves their capability and reduces the tendency to experience vertigo. It, therefore, seems reasonable that sufficient data exists to demonstrate effectively that, in a blind flying condition such as that which would be experienced in MORAY, two men are the absolute minimum which can accomplish the mission.

We find that one of our difficult problems in presenting MORAY is to define the tactical functions. This difficulty probably arises because there are so many uses for MORAY that everybody seems to be discussing a different possible use. We believe that it is true that the MORAY vehicle could replace all of the functions which are now carried out by homing torpedoes. In addition, it has the ability to classify and challenge in peace time. In the case of war, it can verify the target before killing and can remain to verify the kill after firing its weapons. It has often been stated that the best method of verifying the presence of a submarine is to wait for it to sink a surface ship. This is the prime reason for putting ships in convoy in order to be able to increase the rate of loss of submarines. As the danger of air attack makes convoying more difficult, we might expect that the carrying of one MORAY on each merchant ship would make the loss of submarines sufficiently great that the attack of merchant ships in limited warfare would prove to be unprofitable. The Naval Ordnance Test Station would like to carry out a feasibility study on the MORAY concept in order to balance the engineering trade-offs which we heard discussed yesterday as being very important to the accomplishment of a good integrated design. These will be particularly important for this type of vehicle because we will want to have a very low cost, a very high speed, and the minimum amount of weight. We believe that the techniques and tools which we have developed in the design of aircraft torpedoes will make the accomplishment of the MORAY vehicle possible. The aircraft

I would like to begin this discussion by disclaiming any credit for originality in the idea of MORAY. The proposition of a manned underwater vehicle to carry out attack against other craft is not new and, in fact, was put into use during the Revolutionary War using first, augers, and then explosive charges carried on poles. Such vehicles have been built both by the Germans and the Japanese, and the United States has developed many of the needed techniques in the case of the X-1 vehicle. Aerojet made a very reasonable proposal for a 50 knot miniature submarine in 1952. In fact, I understand the tactical need for such a vehicle was even clear to Alexander the Great when he used the masking effects of water to carry out a sneak attack with men protected by a large inverted glass bowl.

The first question which we might ask is why we should approach this vehicle from the weapons side, rather than from the ship side of the family. Yesterday, we heard a great deal about the things which cause a submarine to be heavy. These involve living quarters, heads, access ports, protective bulkheads, and loading and unloading of ordnance while the vehicle is in the water. All of these problems seem to disappear if this vehicle is treated as a torpedo, is recovered from the water for servicing, and is occupied by men for only a short time, as is the case for aircraft-type vehicles. Secondly, this particular vehicle will perform the functions which are now being carried out by homing torpedoes in a more effective manner. It will surpass torpedoes particularly in target discrimination, avoidance of countermeasures, the ability to identify the target before kill, and the ability to report and classify on the kill for short range. We believe that the surface ship now needs MORAY to fight its battles below the interface in exactly the same manner which it needed the aircraft in the last war to fight its battles above the air-water interface. This analogy leads us directly to another question which is frequently asked which involves why we should go to manned vehicles for underwater combat when in the air-combat we are going exactly the opposite direction in replacing manned craft with missiles. This is a peculiar anomaly and the answer can only be found if we consider the changing speeds with which attacks in the air and water are carried out. Bomber and aircraft speeds have been continually increasing without at the same time having a corresponding increase in detection range. This means that, at the present time in the air-combat situation, man no longer has the speed of response necessary to carry out the attack effectively. This is not true yet in the underwater case and probably will not become true for some time because of the much slower speed with which vehicles move in the water. At the speeds existing in water in the foreseeable future, man should be able to outperform the machine.

The second question which we are quite often asked is why a weapons laboratory, such as the Naval Ordnance Test Station, should try to do this particular job in place of some other activity. I believe that the only answer here lies in the fact that this job looks easy to us and that it would utilize the particular skills we have available, and, finally, that we think it would be lots of fun to try to carry it out.

~~CONFIDENTIAL~~

NOTS CONCEPT OF FUTURE ASW WEAPONS SYSTEMS, by Wm. B. McLean, Technical Director, U. S. Naval Ordnance Test Station, China Lake, California. Presented to Undersea Warfare Research and Development Planning Council 16th Meeting, 11-13 December 1962, U. S. Navy Mine Defense Laboratory, Panama City, Florida.

The first problem in establishing the design of an ASW weapon system should be a determination of why the submarine is an important military problem. Submarines normally operate in two different operational manners, and the problem of attacking them may be different in the two cases.

In the first method of operation, submarines constitute a threat to surface ships, primarily when the ships are entering or leaving port, or when they are grouped together in convoys. The range of sonar is relatively small compared to the dimensions of the ocean, and because of the low free-board of the submarine their ability to detect optically is even more limited. It should be expected that submarines will have great difficulty locating surface ships unless they are aided in their job by air reconnaissance, shipping schedules, or geography.

The second method of operation for submarines is one in which they will wish to remain undetected up to the point where their mission has been completed. This type of operation would include the launching of missiles against shore targets, or the long range transport of cargo. At the present time, and I suspect in the foreseeable future, submarines that want to remain undetected should be able to do so except for the possibility of mistakes. This is particularly true if their opponent is kind enough to hunt for them by the use of active sonar. The job of hunting for submarines under conditions where they cannot be forced to disclose their position would seem to be of low military significance because of the low probability of success. Of course we can always hope that the submarine commanders will make mistakes, and we may feel the need to have some capability for taking advantage of these mistakes.

last years

As long as missile-carrying submarines can be assured of operating undetected, it would appear that warfare will remain both limited and non-nuclear except for the possibility of irrational international behavior. We should therefore consider that our prime concern in the ASW problem is sub attack against surface ships where both the submarines and the submarine attacking force will be armed with conventional weapons. In this case, a kill on a surface ship is usually not accomplished with a single weapon, and the submarines will be tempted to disclose their position not only at the time of firing their weapons, but also in evaluating the effect of the weapons on the ship being attacked. This makes our ASW problem considerably easier. In World War II, a ship's convoy provided a solution to the antisubmarine problem by the fact that the sinking of some of the ships alerted the convoy defense to the presence of the subs. At this time, the destroyers and aircraft acting as convoy defense had a considerable speed advantage over the submarine and were able to carry out a homing attack with depth bombs

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and rockets with some probability of kill. We found that as long as we could kill one submarine for every five surface ships lost, a standoff operation was achieved. Since World War II, the range of submarine-launched missiles and the speed advantage of submarines over destroyers has increased to the point where it is now doubtful that the convoy group can attain a kill of one submarine for every five ships lost. The convoy, therefore, loses some of its appeal as a method for protection of surface transport. This is further reduced by the fact that the collection of a large number of ships in a convoy makes their time of sailing and location more easily determinable, and their attack by air and shore-launched antiship missiles relatively easy.

Faced with these problems, NOTS, in consultation with the other West Coast Laboratories, proposed a possible short-range solution for the protection of surface shipping which would take advantage of the size of the ocean by letting each ship run separately and as quietly as possible. Under these circumstances, the chance of interception by either air or submarine becomes much smaller. We have also proposed that it may be possible to provide each transport ship with both an anti-air and an anti-submarine weapon system. These systems would not be sufficiently complicated to allow the detection of an enemy before an attack, but they would provide a reasonably high probability of killing the attacker after his weapons have been launched at the surface ship. Our anti-air weapon proposal would be an optically-aimed homing missile which would not require large search radar or fire control installations. Our studies of the possibility for an anti-submarine weapon have been designated under the code name MORAY. We believe that this system has promise of extending the life of surface transport in the limited war situation. We have therefore constructed experimental units of both systems to investigate feasibility problems and particularly the possibility of low cost construction. The ASW vehicle is now ready for water tests. (Slides, MORAY) The anti-air weapon has also been tested. (Slide, CHAPARRAL)

In the limited war environment, the psychological impact of providing each cargo ship with effective defensive weapons may be of sufficient importance to make their attack unprofitable from the loss ratio standpoint. Anti-aircraft guns in World War II did not produce airplane kills, but firing them reduced ship's losses by 50 percent. Our proposal for the defense of surface shipping has had a reception which has been enthusiastic both in its favor and in its opposition.

The SEAHAWK proposal seems to suffer from some of the same problems. My first reaction, personally, to the SEAHAWK proposal was that the Navy needed more surface ships to defend like it needed a hole in the head. It seemed that the Navy already had plenty of floating equipment to provide adequate targets by which the USSR and her satellites could exert pressure on the government through submarine and antiship missile attacks. Why should we provide them with more capital investment in the form of targets with only minor military significance? However, many wars have been won on the basis of mistakes made by the enemy, and we perhaps need the type of defense which by the use of large numbers of patrolling ships may be in a position to take advantage of any mistakes which the enemy

submarines might make in carrying out their operations.

What can we list as the probable characteristics of a ship best equipped to carry out this mission? We will be depending on having some ships near the scene at which an enemy mistake may occur. Since detection ranges are generally small compared to the area of the ocean, the first requirement for our ship is that it be available in extremely large numbers. The corollaries of this requirement are that it have a low cost, that it be easily maintained, and that it be operable by a minimum crew. We will need this type of ship operating in large numbers over the entire area of the ocean. The large numbers and low cost will make high expenditures for their individual destruction unprofitable. Unless the ship has remarkably long range endurance at a reasonable cruise speed, the logistics of maintaining these ships on-station become insurmountable. We will need a technique for locomotion for these low cost small ships which is not now in operation.

Since we want to exploit random contacts as rapidly as possible, our optimum ship should have a high burst speed, in perhaps the 60-70 knots category, for sufficient periods to carry out effective attacks. Since we expect to be at sea for long periods, our ideal ship should have good seakeeping qualities and be able to maintain speed and stability under rough weather conditions.

Active sonar on this ship will be useful only after we are relatively close to the target because the use of such sonar prior to target detection and closure will provide the target with the information needed to allow it to escape detection. Our ship should, therefore, have a maximum capability in the use of passive sonar detection and should further be equipped with electromagnetic radiation direction-finding equipment which will allow it to listen continuously at all useable frequencies both with radio above and sonar below the surface of the ocean. Passive detection capability is improved if our ship makes a minimum of noise in the cruise condition. Low noise also reduces the danger of alerting the target.

Since these ships are to be available in large numbers, we would expect them to operate in coordinated group activities. They will need the capability of exchanging bearing information on possible targets with the absolute minimum of radio communication. The ability to detect targets which may be below the thermal boundary will be very desirable.

Replenishment of the ships from a submarine tanker, as well as from a surface tanker, would appear to be a desirable characteristic. We will need some antiaircraft protection, and a weapon for antisubmarine action which has a minimum susceptibility to countermeasures. Antiship and shore bombardment capabilities are desirable, but not crucial to the primary mission of our ship.

The above makes a very tough set of requirements for our ship, but I believe that there is some chance that they might be realized if the Navy were willing to undertake a relatively high risk development program on a completely integrated ship which would be the direct responsibility of one

person with some experience in all the areas involved. If the responsibility for the design is more diluted than this, and in particular if the design is to be carried out by committee, I do not believe that the difficult compromises which must be adjusted can be carried out with enough skill to arrive at a workable system. NOTS has certainly not carried out the detailed investigations and the studies of possible tradeoffs in sufficient detail to be able to come up with a Technical Development Plan for a workable ship. However, I would like to propose the following possibilities as one method of approach among the many possibilities which might result in a unique solution.

The only method of propulsion wich comes close to meeting the long range requirements which this ship should have would appear to be the wind. This type of propulsion has been in use over such a long period of time that we tend to treat it from the traditional standpoint, rather than from an investigation of the capabilities which modern technology may have made available to improve this system of propulsion. Sailing catamarans with conventional sails can maintain speeds of the order of 20 knots on runs from Honolulu to San Francisco. The replacement of such sails by low aspect ratio rigid airfoils can probably make improvements in speed and can certainly make significant improvement in ease of handling. This type of hull might provide very good locations for passive sonar detection equipment, and the airfoils would provide a good mounting for radio direction-finding equipment. The low noise requirement in the cruise condition is achieved automatically with a very small expenditure for the reduction of machinery noise. It would be hoped that our airfoil sails could be designed in such a manner that they would stand all types of weather conditions and would not need to be reefed in case of a storm. If this can be achieved it would be expected that they would also provide a high degree of damping of pitch and roll oscillations in heavy weather. The high speed burst capability of the ship should be accomplished using lightweight aircraft-type turbines. A reciprocating engine should be available to provide cruise speed in the absence of adequate wind. Both of these engines, as well as the aircraft and the ASW weapons, should be designed to use a common type of fuel in order to allow exchange of fuel between uses for different missions and under different weather conditions.

For antiaircraft defense, I would propose a vertical take-off and landing aircraft equipped with existing air-to-air missiles; such a plane could also have other useful functions in addition to its air defense mission. The catamaran hull would alternatively make possible the operation of fighter-type sea planes. In my mind, the MORAY type vehicle is the only ASW torpedo which has a reasonable long range immunity to countermeasures. Similar capabilities might be achieved with a wire-guided torpedo if the problem of transmitting information back over an appropriately long cable can be solved. I would propose one of these two weapons to provide the ASW capability of our ship. I believe that a cruise-type missile, utilizing wing and fuselage structures molded from cast plastic bonded explosives, can be built in large numbers for low cost and will provide an excellent antiship and shore bombardment capability.

It is my feeling that a ship of this type can be operated at a much lower cost and with a much smaller crew than would be possible with the presently proposed SEAHAWK system. The choice of weapons does not require the installation of trainable launchers or the associated complex fire control equipment. If the auxiliary power units are used only in the absence of adequate wind or when required to carry out an attack, then the ship will have a much greater on-station time than would be available with the SEAHAWK system. This makes the probability that it will be available when needed to take advantage of a submarine mistake much higher than in the case of a less numerous, less long range system. I believe that several designs with this degree of departure from the conventional approach should be carried through at least to the model stage before the Navy is finally committed to a SEAHAWK type design. The Japanese proposal for a large ASW seaplane is another approach to the ASW problem with quite different merits and demerits. Douglas also has proposed a large 100T low level seaplane using ground effects to increase lift. We might use such planes with MORAY to carry out identification and attack. Many more such designs should be studied on paper in order to select the more promising for model tests.

I would like to conclude with a description of a possible operational procedure for the conduct of limited warfare. The ship just described will provide the Navy with a large number of small, long range patrol craft which can serve the purpose of challenging shipping on the high seas, acting as a police force on the high seas, and to carry out attacks on submarines in the event that they make the mistake of disclosing their position. I believe that such a ship can be used to apply high political pressure with a minimum risk of loss by the fact that they will be available in large numbers. The loss of such a ship in a police-type action is much less likely to provoke nuclear retaliation than would be the loss of an aircraft carrier, such as the ENTERPRISE.

The second Navy function in the conduct of a limited warfare operation is to protect overseas transport in order that the support of the Army, the Air Force, and the Marines may be accomplished. In Korea and World War II, somewhere between 50-75% of the weight of the equipment and supplies shipped for overseas operation consisted of petroleum, oil, and lubricants. If the Army is allowed to improve its mobility by the use of helicopters and aircraft, as proposed in the Howze Board report, then the job of transporting fuel oil will become the major transport problem. I believe that such transport can be accomplished by the use of submarines whose loads would be designed for storage under water at off-shore locations. Such a step would be an important one in our objective of protecting oversea transport. Certainly the storage of large amounts of equipment or fuel oil on the beach in exposed locations will be difficult to defend in any future limited warfare conflict. Harbor entrances also provide a natural geographical barrier to facilitate attacks by submarines. I believe we need to learn to supply our ground troops without the requirement for harbor facilities. If the Navy could manage the delivery of the fuel and the ammunition which will be needed in large quantities by our modern fighting forces, then the delivery of troops and other perishable items by air can become entirely feasible.

U. S. NAVAL ORDNANCE TEST STATION
CHINA LAKE, CALIFORNIA

IN REPLY REFER TO:
Code 01

NOTS PRESENTATION ON MORAY, by Wm. B. McLean, Technical Director, Undersea Warfare R&D Planning Council meeting, Ft. Lauderdale, Florida, 4-6 February 1964

I can be very brief today since the need for depth in getting increased range for sonar systems has been so well documented. The ray bending caused by normal sea-water forces us to go at least as deep as 1500 feet, and preferably to half the depth of the turnaround point of the surface ray, or 6,000 feet.

The remaining question is why we should ask men to go down with the sonar. To me, this is merely a problem caused by the slow transmission of data either through the water or over a cable, together with the great difficulty of dragging cables through the water. At our sonar set we have a lot of data which must be processed, evaluated, and acted upon. If this data can be transmitted to the surface ship and the commands returned to the vehicle, we should do it by remote control. If this is not possible, which I suspect, then we need men in the vehicle.

If we have men present, they can perform other functions such as closing with the target for the purpose of classification and carry out the torpedo's job of killing the target. This will allow/them also to perform the very important function of verification of kill.

Men seem to me to be the most effective mechanism for the avoidance of countermeasures, which we saw yesterday as being very harmful to some of our homing torpedoes.

The advantages of men in our sonar or torpedo are bought with some loss in other areas very similar to the costs which were required to put men in our airborne missiles or airplanes. The launching ship must compromise its performance in order to insure the launch and, more important, the recovery of the torpedo, and experience will probably show that some modification of the ship will be necessary to facilitate the process, as proved true in changing from the battleship to the aircraft carrier.

The psychological fear of diving is probably as great as the similar fear of flying, even though the dangers are probably less. At least the chance of survival in case of equipment failures is greater for diving as evidenced yesterday by the great interest in rescue equipment.

What is the present status of MORAY? We have concentrated on fulfilling the prescribed forms to insure safe operation. The operators have been trained in escape procedures, and the surface crews in recovery techniques. The Bureau of Ships and Bureau of Naval Weapons have both reviewed and approved the program. The vehicle has been checked to 1,000 feet unmanned, and to 120 feet manned, and is now being readied for propulsive tests at Dabob Bay.

The program pursued on the limited scale due to lack of funds has shown that a relatively cheap vehicle with the necessary equipment and buoyancy can be built in the dimensions required. A propulsion system to drive MORAY at 45 knots has been engineered, but not built. The ASTOR torpedo motor incorporated for tests will drive the vehicle at 15 knots but lacks a reverse.

I am convinced that the system is practical and is the best method of solving both the sonar and the torpedo problems. However, it is too expensive and too difficult a job to do well without enthusiastic Navy support.

I visualize MORAY's prime function as the provision of a weapon to surface ships which would discourage their attack from submarines under the conditions of limited war. Its usefulness as a weapon may be questioned on the basis that the prime danger to surface ships is from the air, and the ships may be sunk so fast by this attack that protection from submarines is unnecessary.

Jap 54

AMERICAN INSTITUTE OF AERONAUTICS & ASTRONAUTICS, Symposium on Modern Developments in Marine Sciences, 21 April 1966, International Hotel, Los Angeles, California

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FUTURE EXPLORATION OF THE OCEAN, Wm. B. McLean, Technical Director,
U. S. Naval Ordnance Test Station
China Lake, California

Member, American Institute of Aeronautics and Astronautics,
Ladies and Gentlemen:

I am surprised to be here today. It is amazing that a man who got his degree in nuclear physics and has spent most of his life developing air-launched weapons for the Navy should be selected to make a keynote address on oceanography to a group interested primarily in aeronautics and astronautics. Perhaps, however, this will emphasize that the study of the ocean, far from being a single discipline, has something for every conceivable scientific and engineering skill.

(SLIDE 1)- The ocean is large, covering 71% of the planet's surface. It is deep, extending to a depth of 11 kilometers and having a volume sufficient to cover the whole surface of the earth to a depth of 2400 meters. It is, for the most part, dark with a uniform temperature of less than 4° centigrade. As can be seen from this slide, which shows the percentage of the ocean as a function of depth, most of our interest will lie either at depths less than 300 meters, or at a depth lying near 6 kilometers. The depths less than 300 meters include all of the continental shelves. Most of the ocean depth is near 6 kilometers and only a few trenches reach depths greater than this value.

We have recently heard a lot of emphasis about a national oceanographic program. This will be a difficult program to define because the variety of activities going on in connection with the ocean do not have much more in common than that they are conducted in a common fluid. Also, and that the instrumentation employed to study the

ocean must be especially designed to stand the very coorosive effects of salt water and at the same time resist the effects of the high pressures existing at great depths. Today, I will not talk about the study of general oceanography and the wealth of activities in the ocean because this subject is too big to cover in a short time. Also, it is an area about which I will plead ignorance. Therefore, I will confine my remarks to what I consider to be the most pressing preliminary problem and that is the one of the vehicles which will allow us to reach any area in the ocean which we desire. This is also probably of most interest to a group trained in aeronautics and astronautics.

The feasibility of exploring the ocean at all depths has been demonstrated by the ability of the TRIESTE to reach the bottom of the Mariana Trench. This trip was also historic in that it demonstrated that life can exist at any pressure which the ocean can exert. We have therefore demonstrated the feasibility of exploring at any depth and the fact that there are living creatures at all depths whose study will require a human observer.

It seems clear that at the present time the interest in exploring the ocean as well as the moon is rapidly increasing as attested by the subject matter of this meeting. I would expect this increase in interest to be very rapid since the number of people who can be personally and directly involved is so much larger than the number who can ever hope to go to the moon or operate in space due to the high costs involved. It is also significant that the presently blossoming interest in exploring the ocean does not start from a zero base. Last year, the Citizens of the United States spent something between $2 and $4 billion dollars for recreational use of the ocean. We also have in this country, according to figures from **SKIN DIVER MAGAZINE**, 3 million people interested in diving and about 1 million active divers

who purchased skin diving equipment for the purpose of exploring the ocean to the first 100 meters of depth. A number of vehicles are now operating which can carry one deeper and a larger number are in the process of construction. At the present time there seems to be no technical limits to the volume of the ocean which is available for exploration.

Enough experience now exists with the operation of our present vehicles to draw some conclusions relative to the design of the next generation of undersea transportation. The deficiencies in the present vehicles seem to be, first, limited visibility; second, the lack of operating endurance; and, third, the high cost and difficulties of surface support for these vehicles.

The need for more visibility for deep vehicles is not merely one of needing bigger fields of view for pilot comfort and more rapid search rates, but also limited visibility imposes an important safety problem. The ocean has long been a dumping ground for various types of junk, including cables, lines, ropes, fishnets, etc. If a vehicle becomes entangled with any one of this type of hazard, it becomes very important that the operator be able to visually inspect all parts of his vehicle to determine the degree of entanglement and the best course of action to follow in order to be able to disengage himself as expeditiously as possible from whatever is restraining him. The definite hazards to our present vehicles occasioned by their small viewing angles are what make Mr. H. A. Perry's "The Argument for Glass Submersibles" seem particularly appealing.

(SLIDE 2) - This slide, taken from Mr. Perry's article in the September 1964 issue of UNDERSEA TECHNOLOGY, shows that glass has not only the greatest strength to weight ratio of any material presently available, but, in addition, its resistance to buckling increases markedly as a function of depth. Glass

fails only in tension and the external pressure causes a glass sphere to reach its maximum strength at about 6 kilometers which is also about the maximum depth of the ocean which is of interest to us.

(SLIDE 3) - It therefore seems highly reasonable that our next generation of undersea vehicles will have most of their equipment in the free flooding structure with only the people enclosed in glass spheres (SLIDE 4 and 5) which will allow them to see what is happening and provide them with adequate protection for all depths in the ocean. (SLIDE 6) - Most of our equipment will operate better if it is directly in contact with the cooling effects of the water and it should be easy for the operator to control motors, switches, cameras, tools, etc., through photo-electric signals. We have found no case of a needed electronic component where some commercially available type can not be made to meet the condition of operation at high pressure. Ability to operate at high pressure will undoubtedly become a new, but not necessarily a more expensive requirement.

The short operating time of vehicles becomes increasingly a problem as the depth at which we want to operate increases. Even at depths as great as 2 kilometers the time spent in going from the surface to the bottom and back becomes an appreciable fraction of the total operating time available. This lack of endurance of undersea vehicles can obviously be corrected by application of nuclear propulsion as is being done in the NR-1.

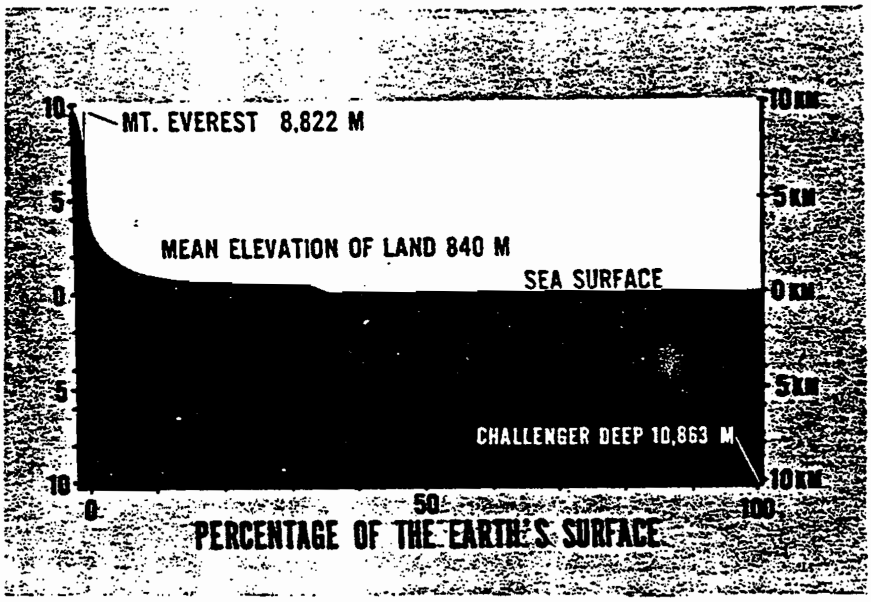
This type of propulsion will probably remain quite expensive, however, for a considerable length of time and will not be available for vehicles for operation by the general public. For the popular exploration of the ocean, it would seem that we would have to be content in the immediate future with the endurance that can be supplied by batteries or thermal heat

sources. For a small vehicle these sources can give us a time below the surface of from 4 to 6 hours which is comparable to that of human endurance in a small space. It also matches quite well what we achieve in fighter aircraft and I would therefore expect that batteries will be adequate to support a considerable program of ocean exploration.

To me, one of the most exciting possibilities relative to man's return to the ocean is that we may be able to free him from surface support and from the problems of surface weather by constructing laboratories operating at atmospheric pressure but having direct access to the sea floor. Dr. Austin, a geologist at the Naval Ordnance Test Station, has suggested that existing mining techniques are adequate for this purpose. He has visited and studied a large percentage of the 40 to 50 mines which are operating at the present time in 14 different countries beneath the sea floor. (SLIDE 7)- These mines have entrances from natural or artificial islands, such as the one shown here at Bell Island, Newfoundland. This particular mine, except for the entrance, is 500 meters below the sea, with a water depth of about 150 meters. (SLIDE 8) - The size of rooms which can be constructed in this manner is unlimited as shown by this picture of an undersea machine shop. In fact, this mine has about 20 square kilometers of area open below the sea floor. I believe it is presently clearly demonstrated that existing mining techniques have the tools necessary to penetrate the bedrock of the ocean floor and will allow us to establish a laboratory of any desired size. (SLIDE 9) - We can visualize an installation with an entrance from an island which might be located close to a fault zone where geothermal power would be available and we could provide the electricity needed to operate our laboratory by the temperature difference existing between the earth and the

tremendous reservoir at 4° centigrade in the ocean. Vertical shafts in our laboratory will make convective cooling of both the power plant and the laboratory working space relatively easy. (SLIDE 10) - As a next step, we could start our laboratory by drilling an opening in the bedrock completely underwater. We would then install a lock, a pump, and a nuclear power plant which would allow us to inhabit the opening at atmospheric pressure. Once we have access and the power to be self-sufficient, we can continue to enlarge our laboratory and dwelling spaces to any desired size.

In summary, then, I believe that we can predict that interest in the ocean will continue to rise as our technology makes more of its volume available for exploration. Glass will be used as the enclosure to protect the people and at the same time give them the maximum contact with their environment. The rest of our equipment will be designed so that it can withstand the ambient environment existing in the ocean at any depth. The freedom from the delaying effects of weather at the surface and the costs of surface support will be achieved by underwater laboratories, underwater entrances to the ocean floor, and self-sufficient diving vehicles. The cost of building and operating deep diving undersea vehicles will come down until they are as available to the private individual as ocean-going small boats are at the present time. We will hear more about many vehicle concepts this afternoon. Both the number of individual vehicles and the types of vehicles available can and should increase enormously in the next 5-10 years. I expect that in underwater vehicles we will see something similar to the growth of aircraft designs in the last 60 years. But, because of our exponentially expanding technology, the development of new special purpose undersea vehicles will occur much more rapidly than did the proliferation of aircraft types and the numbers of individual aircraft in the past. No new breakthroughs in technology are needed. We are now ready to go under and open a new area of industrial products.



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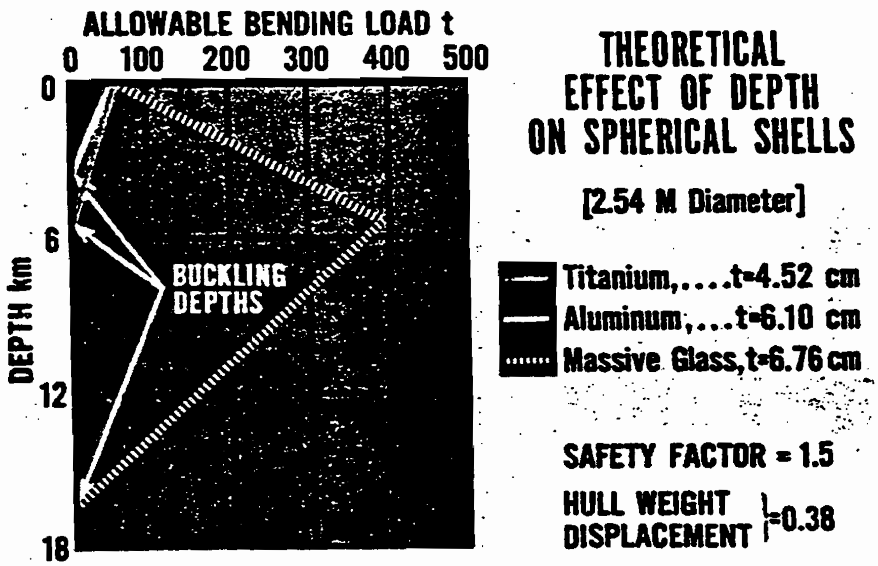

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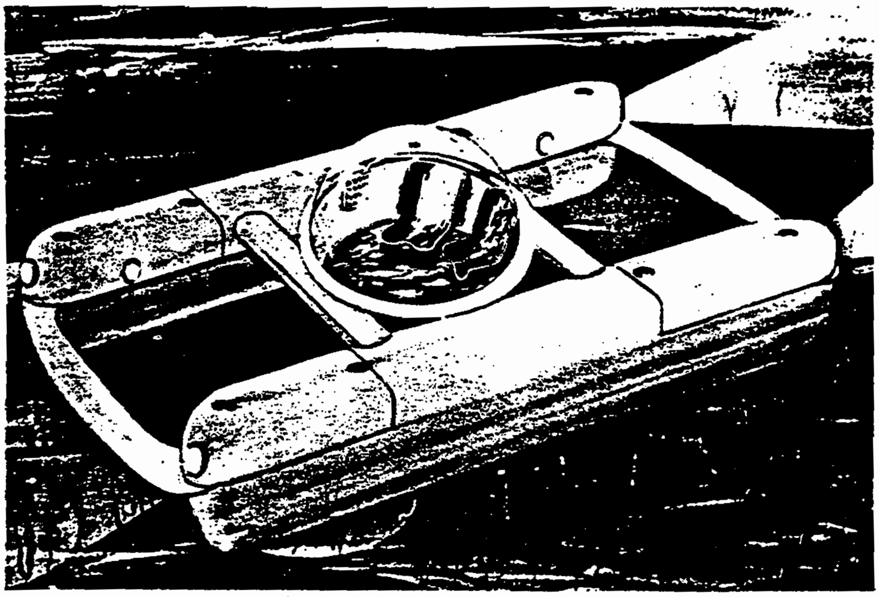

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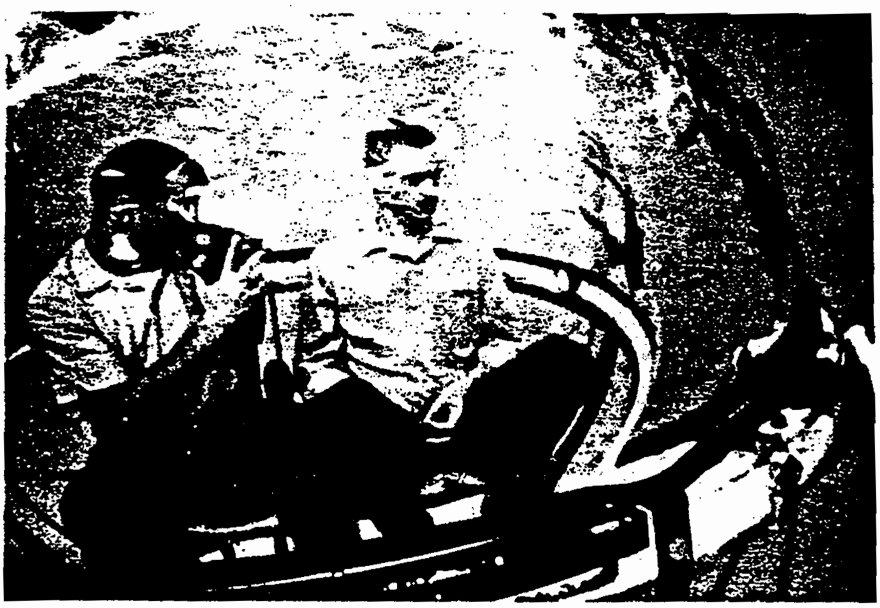

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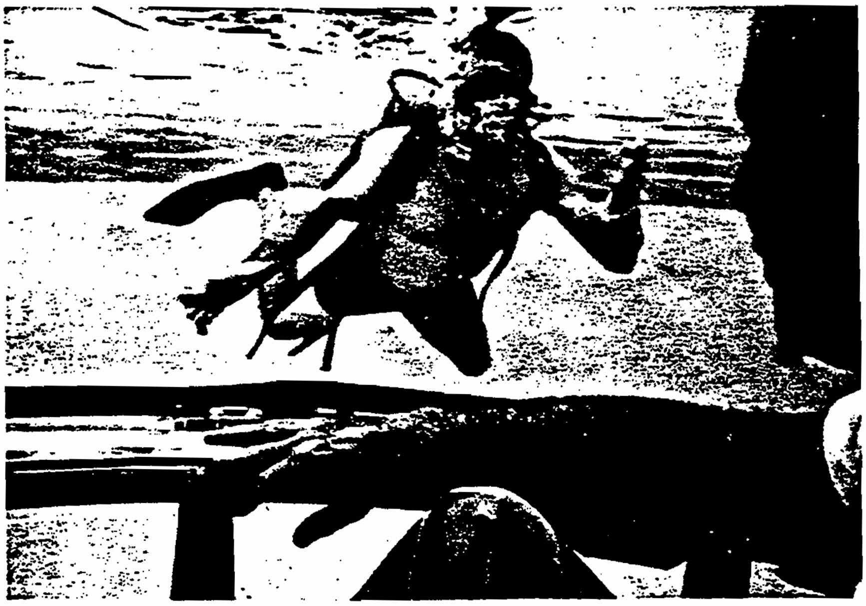

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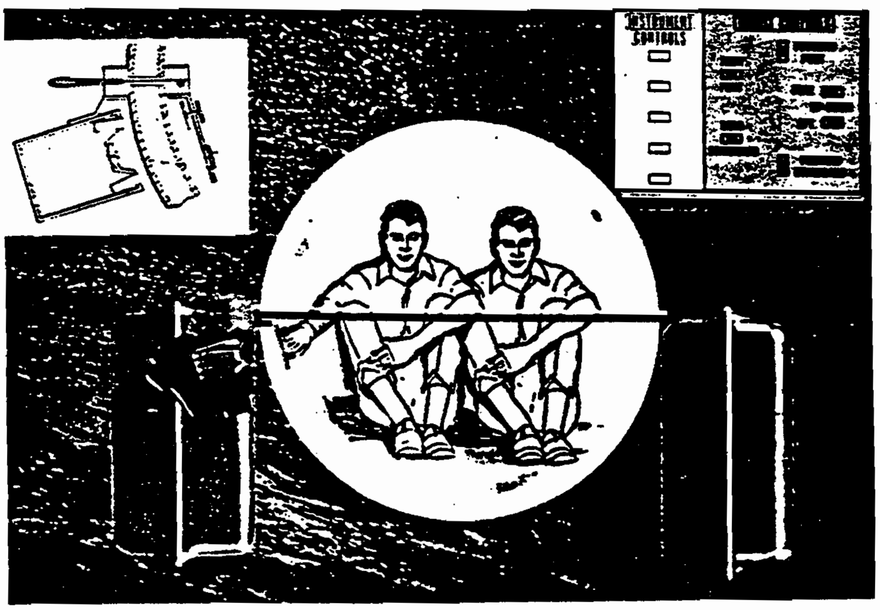

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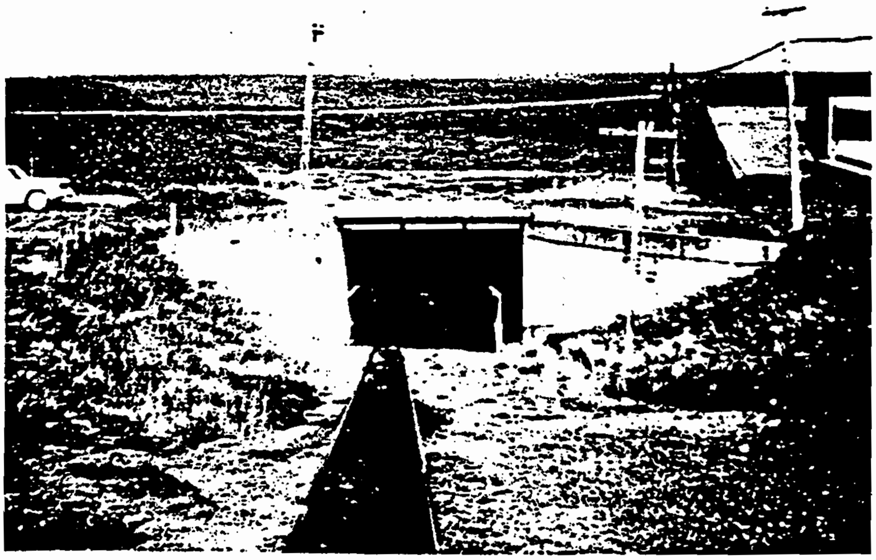

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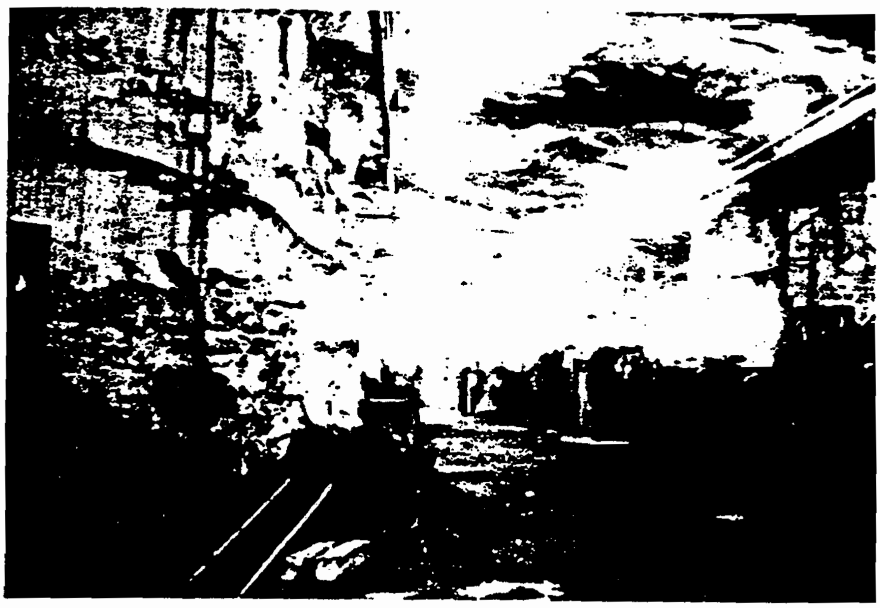

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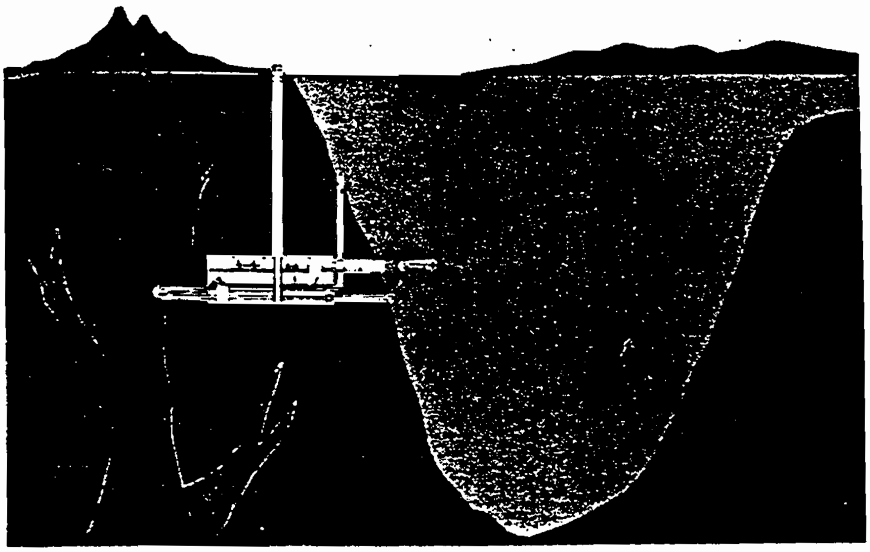

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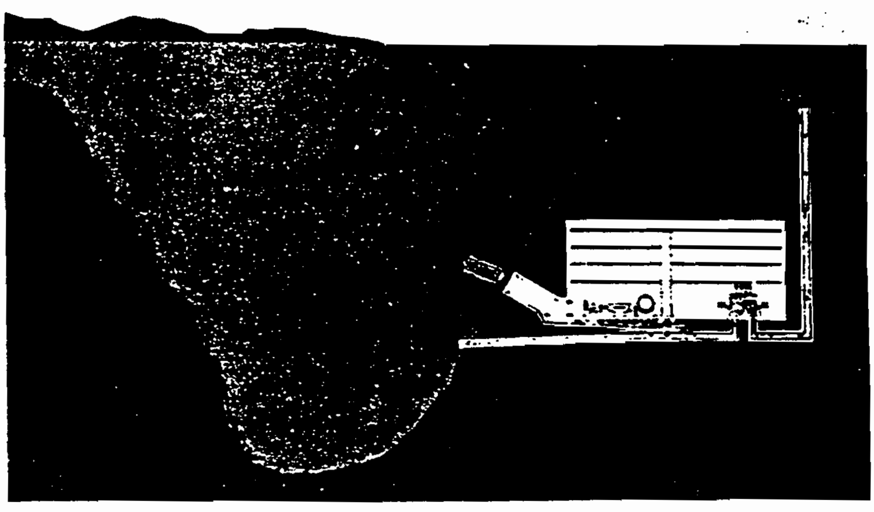

Slide 10

Wednesday, 8 January 1975

SURVIVAL OF THE NAVY AT SEA

Dr. Wm. B. McLean

Ladies and Gentlemen--

I have been asked to make some predictions on the future needs of the Navy, and to me that means that we must start first with the description of the jobs that the Navy must perform.

I believe that the first job of the Navy is to continue to maintain an invulnerable sea-based deterrent as is now represented by the FBM submarines. In addition, I believe it will have to maintain political pressures and natural visibility in a large number of places involving most of the area of the ocean. The new regulations proposed by the Congress of the Sea will require that the Navy monitor everything out to 200 miles, and the extended interest of the oil companies in undersea operations will require the Navy to inspect these installations for pollution and perhaps even to protect them against sabotage.

I visualize that these two missions of the Navy, maintaining invulnerability, and inspection and protection will be its prime areas of operation in the future, but it will be faced with some technical facts which must be taken into account if it is to carry out its operations in an optimum manner.

The location and identification of objects on the surface of the earth particularly those which have the clear background of the sea is becoming increasingly easy and the accuracy is continually improving, and if one is willing to expend the effort required, objects at sea can be located with adequate accuracy to make their targeting straightforward.

The design of missiles to hit targets wherever they may be, continues to be costly, but it is straightforward from a technical standpoint, and I am sure that this Laboratory can take a major role in reducing the costs.

A second and equally important technical fact is that the locations of objects below the surface of the ocean continues to be difficult because of the variability and the opacity of sea water. All known forms of radiation penetrate it very little and this contributes to insuring that submarines are now and will continue to be relatively safe, even though their operations may be limited by the same characteristics of the ocean.

The third technical fact is that the Navy and the country need ocean transport in addition to other forms of transport, such as air, because the density of water makes it possible to support large loads and to move them easily at reasonable speeds. We have heard considerable discussion of the 80-knot Navy. To me this would be fun, but not necessarily very practical. If we want to go at such higher speeds we should probably look to the use of aircraft rather than a change in the design of our naval ships because the viscosity of air is so much lower and the speeds of aircraft necessarily must be higher than those of ships.

Fourth, if our ocean transport becomes endangered because of attack from foreign nationals or commercial pirates, the most cost-effective way of protecting it is to submerge it. This alternative seems to be highly controversial, probably because the only nation to utilize submarine transport lost the war in which they were engaged.

We have discussed many times the importance of dispersing targets and reducing individual value in order to promote their total survival. Since with our modern detection systems, all surface ships are available for attack, we should expect a reasonable loss rate. As the loss rate increases it becomes continuously more obvious that we must have larger numbers of ships in order to survive. The requirement for larger numbers means that the ships must be smaller-and-less expensive in order to fit a fixed or reduced budget. The small size carries the penalty of short range and the need for new hull designs to increase ship stability in high sea states, so that they can survive and also be capable to operating aircraft. The small size also brings with it the penalty of limited endurance unless we resort to sail. Any other alternative requires refueling and in any environment where the ships are endangered the tankers will also be valuable targets unless they are submerged.

In my mind the first indication that the Navy intends to survive and win a limited war conflict at sea using non-nuclear weapons will be when they start the research on submarine tankers and submarine transport. Without this capability I see no possibility for long term survival of naval forces.

I believe the technical solution to the Navy's problems is very straightforward. That is lots of small ships refueled by submarine tankers. You may ask when it is so difficult to start the Navy moving in this direction. I know that all of us have felt some degree of frustration at the slowness of our government machinery in accommodating change.

The time I have spent in thinking about the problem of what inhibits change has led me to the conclusion that much of the difficulty is caused by the fact that in our presentations we do not distinguish clearly enough between budgetary, political, and technical reasons when we are trying to reach important decisions. Most arguments are disguised as technical arguments, even though they may be primarily budgetary or political. For example, I have not seen a technical justification for a new FBM submarine, but it is obviously very important both from the budgetary and political standpoints. We have had aircraft carriers operating in the Gulf of Tonkin over the past several years even though it is abundantly clear from a technical standpoint that they should be very vulnerable during these operations. In spite of their technical vulnerability their political protection was entirely adequate; however, if we were to write a requirement that this political protection should be replaced by improvements in technical capability, we may well find that it will be impossible to do so within our budgetary constraints.

In both peacetime and wartime, the political aspects of our problems must dominate in our decision making process because the final intent of all warfare is to promote political decisions.

As we get further away from wartime, the budgetary considerations will become more important. In wartime in contrast the importance of budgetary considerations is always suppressed--anything that is needed must be supported. Part of our present problem is that we are still operating under a budgetary procedure established in wartime. We ask the military

services to prepare a list of the things they need, and then Congress must concentrate on finding the weakest elements in the programs. The services concentrate on defending all of their line items, not because they believe they are all equally important but because they recognize they can operate best with the largest budget that can be approved. No tradeoffs are possible under this system. Consider how much time and effort could be saved if Congress were to assign budgets and missions to the services as is done in the Soviet Union and then concentrate on a review to examine the programs which most effectively support the assigned missions. This would lead to much more discussion of the technical aspects of our military programs and less on cost overruns. Under such a system we might see the Air Force and the Navy trying to shift the responsibility for maintaining deterrence to the other service, if either of them could move the money involved to more ships or to more aircraft. If we were to plan our budget from the top down, we could at least save 50 percent of the technical manpower now devoted to relatively useless budgetary procedures. Many man-hours of labor now wasted could be put to productive planning of research and development.

I would therefore recommend that if the Navy wants to continue to survive on the surface and under the sea, it must start necessary research to build undersea transport and particularly undersea tankers in order to supply the numerous small ships that it will need in order to exert political pressure in all areas of the world. In order to do this we will probably need some changes in the budgetary process.

Some 20 years ago I reached the conclusion that advanced planning only made sense on the basis that the world will learn to conduct warfare without the use of nuclear weapons. If we make the assumption that nuclear weapons will be used, then it is clear that military operations will be of very limited duration, and that we need to consider more drastic measures for survival such as the installation of self-contained undersea cities, such as those proposed by Carl Austin in a Naval Weapons Center Study titled "Rocksite."